

Maintenance, renovation and energy efficiency in the Swedish multi-family housing market

ABOLFAZL SOUSANABADI FARAHANI

The department of civil and environmental engineering
The division of building services engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, 2017

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ISSN 1652-9146

Licentiate / Department of Civil and Environmental Engineering,
Chalmers University of Technology
Lic 2016:09

Department of Civil and Environmental Engineering
Division of Building Services Engineering
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-7721000

Chalmers Reproservice
Gothenburg 2017

The project has been financed by the Swedish energy agency.

Summary

Residential buildings accounted for almost a quarter of the total energy use in Europe in 2013. Considering its significant share, energy efficiency in the residential sector has been a crucial part of the European Union plan in achieving the energy and climate objectives of 2050. In this sector, having the low rate of new construction in mind, the existing building stock represents the biggest potential for energy savings. This situation is no different in Sweden with the housing stock taking up to 23% of the total energy use. Although, the sustainable development in the country has driven its territorial carbon emissions beyond the average EU performance level (Minx, Scott, Peters, & Barrett, 2008), the need for energy efficiency in the housing sector is imminent.

The construction boom during 60s and 70s in Sweden resulted in the rise of more than a million housing unit around the country. Today, a large share of this stock is in urgent need for extensive maintenance and renovation measures which presents a unique opportunity for implementation of energy efficiency measures at marginal costs.

In Sweden, this opportunity however is not well communicated. Attempts have been made in various renovation projects yet energy renovation methods are to be perceived cost effective. There are systematic and fundamental problems on the way of energy renovation which hinder its progress, i.e., the characteristics of the Swedish housing market; regulations; the low energy price; socio-economic issues and lack of strategic planning in property management.

Renovation issues are in principle sustainability problems. Financial, ecological and social challenges are what make planning for renovation complicated and cost inefficient. These problems bear specific characteristics which have marked the features, differences and challenges in the development of the Swedish housing market. Today, having around 600 000 apartments in need of extensive maintenance and renovation measures, the main problem remains to be the difficulty in systematic implementation of maintenance and renovation measures with regard to technical and socio-economic difficulties.

In this study, to deal with this issue, a method has been proposed that can be used to budget and plan maintenance with regard to renovation and energy efficiency time frames. The application of this method for the current situation, besides strategic maintenance planning, is the opportunity it offers for prioritizing maintenance and renovation measures in older properties under budget restrictions. This method is further used to study the effects of different maintenance strategies on both the economy of the housing companies and the economic life of the respective properties.

Results from this study illustrate the benefits of a proper maintenance strategy and indicate the importance of modernization (renovation) and energy efficiency in the extent of properties' economic life. This study, furthermore, points at existing potentials for improvements in the financial performance of existing maintenance strategies with regard to renovation and energy efficiency.

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1. Introduction

As the evidence of climate change was better understood during 90s, a strong international movement was emerged to take action and commit to certain level of reduction in greenhouse gasses (GHG) emissions in the interest of human safety in the face of scientific uncertainty. This international concern became the basis for climate negotiations amongst all Parties of the United Nations Framework Convention on Climate Change (UNFCCC) in 1997. These negotiations resulted to an agreement on the level of GHG emission reductions amongst all member countries (The Kyoto agreement, KP). Considering the KP's short timeframe, 2008-2012, in order to play a leading role in upcoming negotiations, the EU decided on adopting its own climate plan in 2008 and set even more ambitious targets than the KP's, drawing energy and climate objectives for the next 40 years. In 2007, the EU announced that its developed countries would commit to 30% reduction in GHG emissions (compared to the 1990 level) by the year 2020. The plan, in addition, included commitments to increase savings in EU's energy use and the use of renewable energy by 20% by the year 2020, (Council of the European Union, 2007).

Ever since, on promoting the energy efficiency, there has been concerns regarding the share of real estate sector in the total energy use of the European countries. Buildings contribute to almost 40% of the total energy use and 36% of the total CO₂ emissions in Europe, (BPIE). In Sweden, the share of the real estate sector in the total energy use has been more or less the same while mitigation efforts toward the use of renewable resources have driven the CO₂ emissions in this sector to low levels comparing to the reference year (SCB). Having reached the EU's targets for GHG emissions in buildings, the problem remains to be the energy efficiency in this sector.

During the past few decades, along with introduction of new energy requirements and energy certificates for new constructions, the government has introduced programs and subsidies to facilitate energy efficiency in maintenance and renovation of the existing building stock. Despite all the efforts, the progress yet seems to be stagnated. Considering the current condition of the building stock and the need for extensive maintenance and renovation measures, in order to exploit the given opportunity, it is crucial to identify key points explaining the low pace of renovation and energy efficiency in the housing market.

In this chapter, an introduction is given on the current situation of the multi-family buildings, the rental housing market and its governing laws and regulations. Furthermore, the development of the Swedish housing market is studied to investigate the effects of the market and its characteristics on the creation of the current situation with poor housing condition and intensified housing shortage.

1.1. Energy mix

As mentioned earlier, the real estate sector is a major contributor to the total energy use in Europe. Out of the total 40% share of the real estate, according to (Eurostat, 2015), households in 2013 accounted for 26.8% of the total energy use, whereas in Sweden this share was about 23% (81 TWh) (Energimyndigheten, 2015b). Figure below (Figure 1-1) illustrates changes in the total energy use (heating and electricity) in households and the respective GHG emissions during 1995-2013. In this period, the total energy use in households has been decreased by about 16,7% in total from which the share of single-family and multi-family units were 23,6% and 11,2% respectively. The total heated area (A_{temp})¹ in this period has been increased by 8,5% in total with single-family and multi-family units contributing to 15% and 6% of the increase in the relevant stock, respectively, (Energimyndigheten, 2015b). It is obvious that the energy performance of the multi-family buildings, despite having higher energy use and lower share of added heated area, has not been addressed properly. This increase in the number of households resulted in increased use of electricity, whereas the introduction and use of energy efficient systems and appliances have been the offsetting developments parallel to the increased heating area, (Energimyndigheten, 2015b).

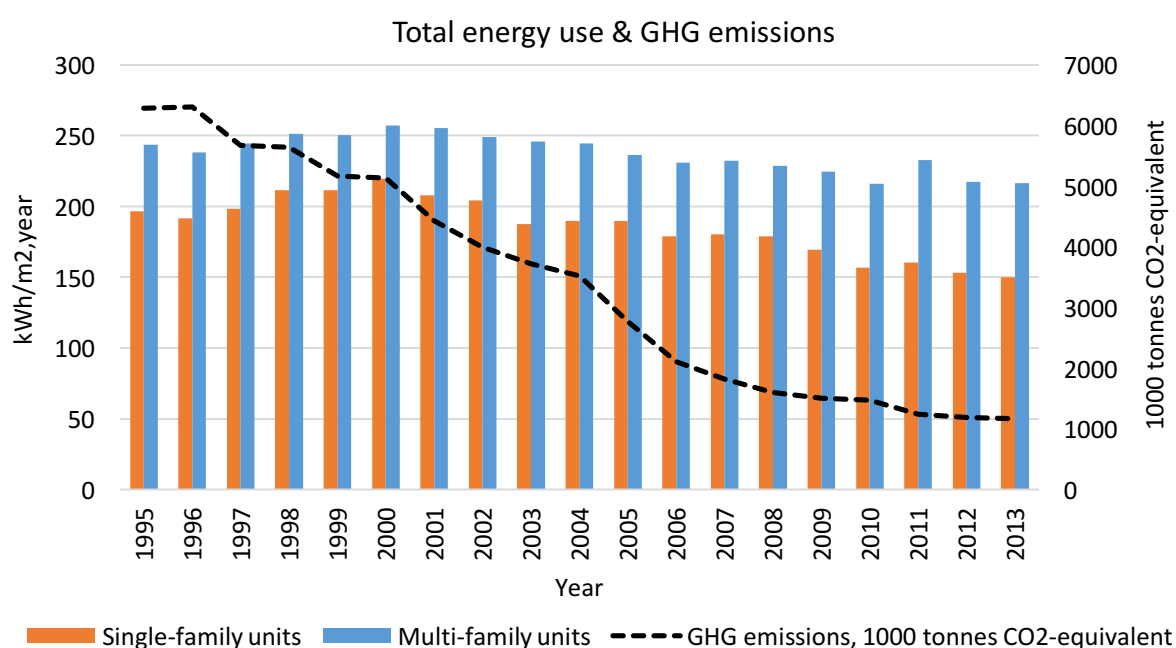


Figure 1-1: Total energy use and the respective GHG emissions in households in Sweden, (Energimyndigheten, 2015a, 2015b)

While the total energy use in residential buildings has slightly decreased comparing to the respective level at 1995, the composition of energy sources has changed prominently. The

¹ A_{temp} is the enclosed interior area of the building envelope of all floors, attic floor and basement, for temperature-controlled spaces, intended to be heated to more than 10 °C, (Boverket, 2015b).

direct use of fossil fuel, in relation to the total energy use, has noticeably decreased from 30,6% to 2,5% by the year 2013 which resulted in 82% reduction in GHG emissions, (the dashed line in the figure above). This has happened mainly due to the strong incentives for the housing owners created by the high energy price tag during 70's oil crises, to switch from oil based heating systems to district heating, heat pumps and pellets.

1.2. Energy and climate policies

The environmental policies in Sweden in form of investment subsidies and information campaigns were already introduced during the 1970's and 1980's, when the oil crises together with serious environmental issues led to policy measures and stricter legislations. Using these policies, Sweden managed to reduce its CO₂ emissions by around 30% before 1990, (Regeringen, 2008a). This reduction, while the total energy use had been increased, happened mainly because of the increasing share of electricity in the total energy use. At the same time nuclear and hydro power became the dominant sources of the Swedish energy mix. Later on, through the energy and climate policy resolution of 1991 the Swedish government initiated the world's first significant carbon dioxide tax. In 1993 carbon dioxide tax reductions were introduced for industry while the general tax on carbon dioxide was increased. Besides, an international perspective framework was introduced to ensure that the country would not assume a significantly heavier economic burden comparing to the reference industrialised countries, (Regeringen, 2001). As a result, by the end of 1999, the GHG emissions were already below the 1990s level and by the year 2007, it reached 9,1% below the 1990s reference level, (Regeringen, 2008a).

Sweden however, as a pioneer in climate policy, has faced strong challenges to keep up with its energy efficiency objectives. These objectives have been formulated most often more ambitious than, yet strongly influenced by, the EU energy and climate policies. In 2008 the country set its ambitious climate and energy targets for the year 2020:

- reduction in greenhouse gas emissions by 40% below 1990's level,
- 20% lower energy intensity comparing to 2008 (20% lower energy use per heated area in households and locals comparing to 1995)
- and 50% share of renewable energy resources in the energy mix, (EPBD, 2010; Miljomal, 2012; Regeringen, 2008a).

Having set ambitious goals, cost effectiveness remained to be an important notion in government's guidelines toward energy and climate objectives. Government's attention to the economy of the energy efficiency measures was followed by neglected, missed and displaced opportunities for cost effective energy efficiency improvements which created the so called "energy efficiency gap". This inefficiency caused abundant economic loss. The resolution on climate policy in 1991, the energy policy in 1997, the climate strategy guidelines on procurement, introduction and demonstration of new technologies, the introduction of energy certificate to promote efficient energy use in 2006 and the long term

commitment to research and development were all in line to develop an ecologically and economically sustainable energy system in Sweden, (Hirst & Brown, 1990; Högberg, Lind, & Grange, 2009; Regeringen, 2006, 2008a).

However, despite all these efforts, most of the investments in energy efficiency measures in real estate sector have been limited to the new constructions in residential buildings, while the rate of new construction in Sweden, has remained almost constantly below 2% of the respective existing building stock for the last 20 years, (SCB, 2015a). The little share of new constructions in the building stock and the consequent minor effect of its low energy use, while being a necessity, indicates the huge energy efficiency potential in the existing residential building stock.

1.3. Swedish residential building stock

It is often discussed that there is a huge potential for energy efficiency in the existing building stock. Since the need for energy efficiency has been properly communicated, to determine factors stalling its progress, it is important to study the characteristics of the Swedish residential building stock. The knowledge gained can help us identify and prioritise energy saving potentials of the target building stock.

1.3.1. The development

The economic boom and social prosperity of the post second World War (1945-1960), resulted in severe housing condition as more and more people moved to bigger cities. Even though during these 15 years, 570 000 apartments were built to solve the housing problem in the country, due to poor housing quality², population growth and quick urbanization, housing shortage was imminent during early 60s. As by the year 1960, in Stockholm alone, 106 910 people were in the waiting list for housing, (Boverket, 2007). Poor housing condition beside long waiting lists in growing cities became a political burden for the social democrat party. Therefore, in 1965, the government took a holistic approach to the housing problem similar to the decision in 1945, to build 100 000 apartments per year from 1965 to 1974. The decision meant extra financial support to boost the already high rate of production, around 80 000 apartments per year, where municipalities were given more support thus extra responsibilities for planning and construction, (Boverket, 2007; Hall & Viden, 2005; B. Roos & Gelotte, 2004). The program was called Miljonprogrammet (The million homes programme). The high rate of construction activities in this period has been the highest in the Swedish real estate market since 1945. Figure below, (Figure 1-2) shows the development of the residential building stock in post second World War Sweden.

² During 15 years from 1945 to 1960, 822000 unit apartments were built in Sweden. However due to lack of proper standard, meanwhile extensive demolition of housings was happening in the country. The main problems with existing apartments, among other things, were: inappropriate size often too small, 64% had no toilet, only 21% had shower, one third had access to electricity or gas and only 11% had refrigerators, (Boverket, 2007).

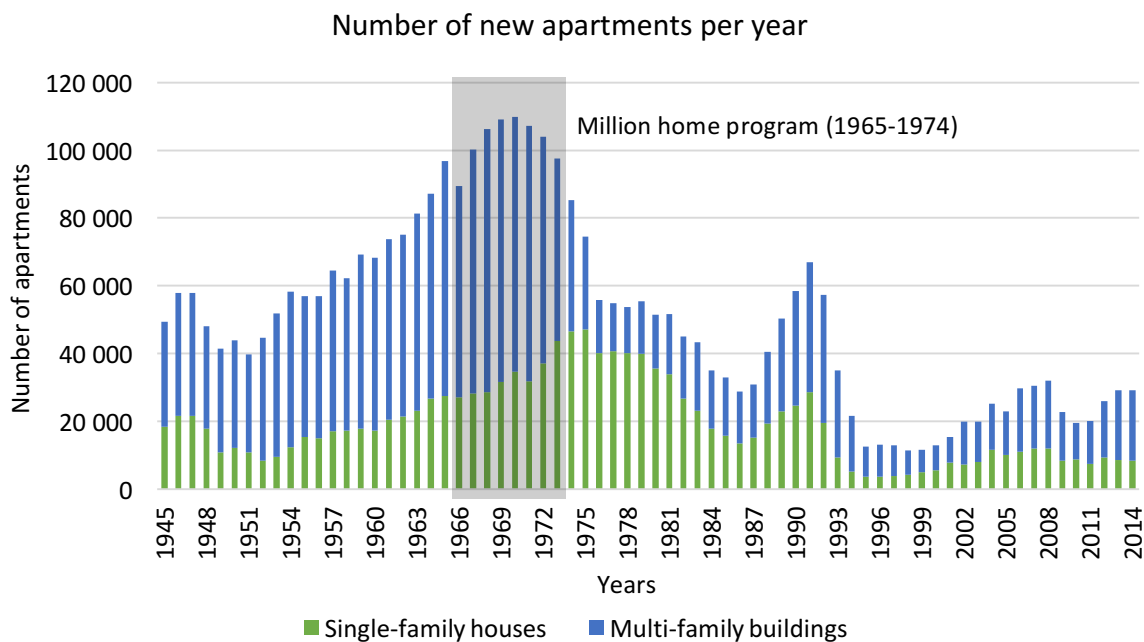


Figure 1-2: Number of new built apartments in single-family houses and multi-family buildings in Sweden, (SCB, 2015a)

Due to extra incentives and support, municipal housing companies took the majority of the construction work and owned the largest share of the million homes program apartments. Among all types, multi-family buildings were prioritized because of housing subsidy conditions such as tax-free status, favourable subsidies on mortgage interest rate, land acquisition and construction permits, (Hendershott, Turner, & Waller, 1993), as well as for being more time- and cost-efficient in large scales. As given in the Figure 1-2 multi-family apartments were the dominant type of housing construction during this period, (1965 - 1974).

By the year 1975, there already were a lot of apartments standing vacant which is on reason why there was a sharp decrease in construction activities by the end of the million homes program. Thereafter, the construction rate remained almost constant till early 80s. During this period, the low rate of construction, demolishing old and low-standard units and the population growth led the housing market toward an equilibrium by the early 80s. In the beginning of the 80s, there were already many housing units in need of maintenance and renovation measures. The ROT program was then introduced to not only solve this problem but also help the high rate of unemployment. During the period 1984 - 1993, this program extended to cover the maintenance and renovation of more than 400 000 housing units and helped overcome the problematic unemployment situation, (Boverket, 2003).

It was during late 80s, when policies in the housing market once again shifted toward new construction. The low vacancy rate in late 80s, improved real GDP, better unemployment condition, increased housing prices, low real interest rates, strong mortgage interest tax

deductions along with already existing housing subsidies³ triggered the high rate of construction which initiated the so called 90s housing bubble. Considering the fluctuations in demand and supply and volatile housing prices and the 1990s economic recession, it did not take long for the market to collapse which resulted in the early 90s housing crisis, (Hendershott et al., 1993; Jaffee, 1994; Worldbank, 2015).

Ever since the 90s housing crisis the market has not fully recovered as the production rate has remained very low (below 2%) during the entire period. Following the 1990s recession, the main reasons behind the decrease in new production and at the same time high rate of demolishing of multi-family buildings were: the depressing economic condition; high number of vacant apartments; low investment in construction; difficulties in the construction labour market and decreased real GDP, (Jaffee, 1994). Figure below, Figure 1-3, illustrates the relationship between number of determinants in the Swedish housing market⁴ during the 90s housing crisis.

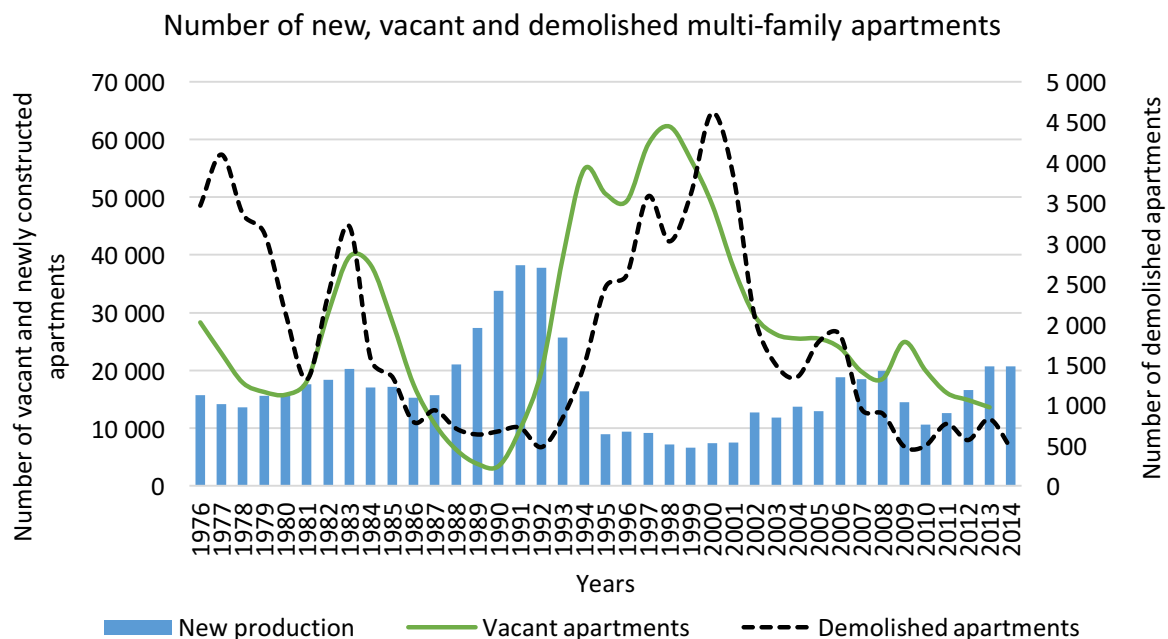


Figure 1-3: Number of apartments in new construction and demolished multi-family buildings as well as the number of vacant apartments in multi-family buildings in Sweden, (SCB, 2015a, 2015c, 2015h)

As it is shown in the figure, the number of new production and demolished multi-family apartments follow the number of vacant units of the respective type which highlights the vacancy rate as one of the main determinant in decision making in the housing market. According to (SCB, 2012) more than 90% of the demolished apartments were knocked down due to the high rate of vacancy. As it can be noticed, there is a lag (couple of years)

³ By the year 1990, housing companies were expecting reduction in housing subsidies in coming years which made them produce more units while subsidies were still in force, (Jaffee, 1994).

⁴ This graph shows the dynamic only in the multi-family buildings market.

between the time changes happen in the number of vacant units and in the number of new productions and demolished apartments. This lag can be explained by the relatively long process of planning in construction works in real estate market. This also clarifies the high rate of construction up until 1993 even though the signs of crisis were evident to housing companies in early 1990s.

As it can be seen in the figure, throughout the 90s, the housing market remained depressed with low production rate while many vacant properties were being demolished. It was in the beginning of the year 2000 when the housing market started to recover from the earlier depression, taking advantage of low interest rates, rapid economic growth and lack of new supply. The development has continued up until today despite the little set back in 2008 due to the world economic crisis.

Reviewing the history of the multi-family building stock, it is important to know what type of tenure these buildings are comprised of. Different tenure situation creates different local governing bodies, the structure of each influences the decisions made in the management strategies of the respective properties.

1.3.2. Types of tenure

In Sweden, there are three types of tenure in multi-family building market as follows:

1. Hyresrätt (rental): rental apartments are those units owned by the owners other than physical persons, estates or housing associations, which are rented out in the Swedish rent-regulated market. During the million home program (1965 – 1974), rental apartments comprised the majority of the new construction in multi-family buildings. By the year 2015, about 60% of the total multi-family building stock were rental apartments, (SCB, 2015g).

Unlike most other countries in Europe there are no low cost, social housing in Sweden. Instead rent allowance is one of the main components of the Swedish housing policy through which low-income families can receive a monthly payment to cover a part of their housing costs, (Försäkringskassan, 2015).

The rental housing market in Sweden is uniform and terms are equal for both municipal and private housing companies. The rent regulation is a comprehensive rent control system based on two important features: a comparatively large public rental housing and a well-established tenants' association, through which rent levels are negotiated and kept constantly below the market level for both the current and new tenants, (Turner, 1988).

2. Bostadsrätt (condominium): condominiums are referred to as a form of tenure where a part of a multi-family building (an apartment) is individually owned. In this case

the association of owners jointly represent ownership of the whole building. Property tax reforms of 1990 and mid 2000s have strongly encouraged home-ownership in Sweden⁵. The increased demand for owner occupied housing has shifted the investment from rental apartments to private ownership units as the total share of newly constructed apartments for sale has increased from 24% in 1990 to 50% of the total construction in 2015, (SCB, 2015e).

3. Äganderätt (ownership): The ownership is a type of tenure where the residents own the apartment and control the rights individually. This type of ownership comprises the minority share with total number of 666 apartments in 2015, (SCB, 2015g).

Considering the management complexity of the rental apartments which is to great extents influenced by the rent regulated market, this study focuses on this type of tenure, however, principles discussed in this study can also be used (adopted) for the other types of tenures.

1.3.3. Geographical distribution

production rate during late 80s and early 90s as a result of these low vacancy rates and increased housing prices led to a slight increase in vacancy rates in bigger cities whereas, in the rest of the country on average a 5% increase could be observed, (Jaffee, 1994).

As it is shown in the figure below, during the first 5 years (before and after the housing crisis), the total number of new apartments only matches the population growth in Figure 1-4, as for the three bigger cities the population growth clearly outweighs the number of new apartments. This misplacement is more evident during the next five years, 1995-2000. During these years in bigger cities, the population growth continued to outweigh the production rate, while in the rest of the country, the sharp decrease in population due to post recession urbanization was met with yet again high production rate. As by the year 2000, for around 300 000 added population in three bigger cities, about 65 000 more apartments were built in the rest of the country.

⁵ For more information check (Stenkula, 2014)

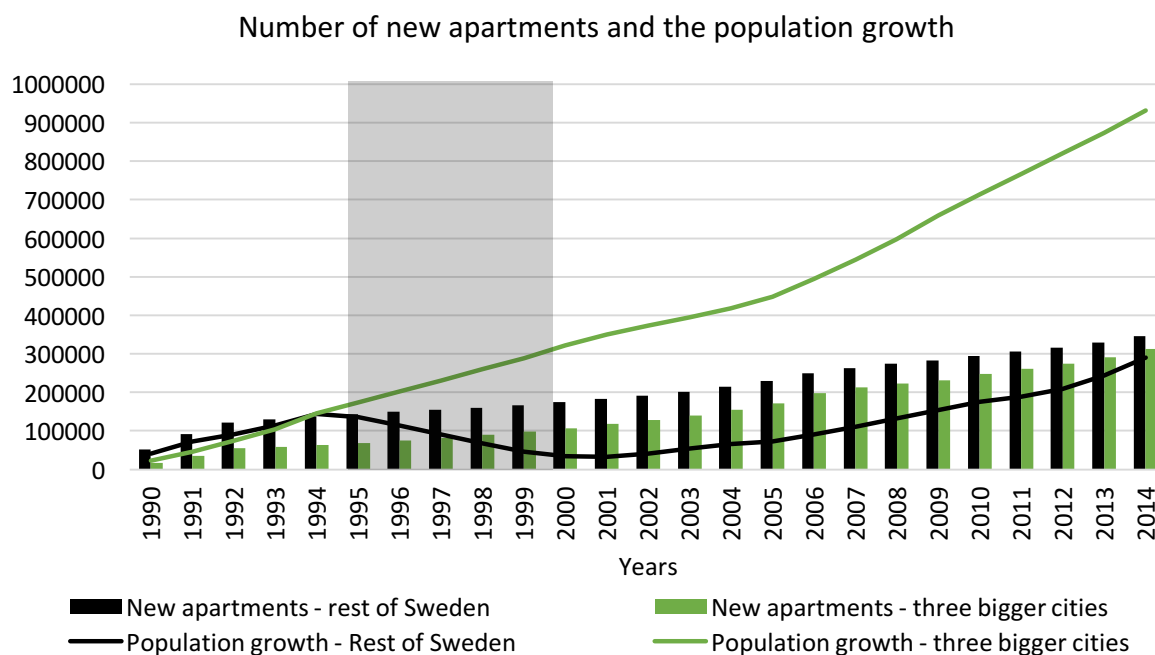


Figure 1-4: The accumulated population and the number of apartments in new construction for the greater Stockholm, the greater Gothenburg, the greater Malmö and the rest of Sweden, (SCB, 2015a, 2015f)

As discussed in (Boverket, 2013a) the problem with housing shortage in Sweden in recent years is only limited to metropolitan areas and does not indicate the quantitative shortage of housing in Sweden. This poor geographical distribution of housing stock along with the current low rate of new production leads to very high vacancy rates in smaller cities and long waiting lists in metropolitan areas. According to (SCB, 2015h), more than 75% of the total vacant apartments in multi-family buildings are located in smaller cities with less than 75000 inhabitants⁶.

Since the majority of rental housings come from multi-family apartments, shortage of rental units in three biggest cities in Sweden, where more than half of the Swedish population reside, makes access to affordable housing difficult for many people living in these areas. On the other hand, the high vacancy rates in smaller cities create financial problems for the housing owners. These properties usually generate low revenue which makes it very difficult for the owners to optimize income. Some gets demolished and some are left with the least maintenance activities. These apartments, today at their 40s, are in need of extensive maintenance and renovation measures which has imposed serious financial challenge to the housing owners.

1.3.4. Technical condition and energy performance

There were, by the year 2014, about 4,67 million housing units in Sweden, from which 50% were multi-family apartments, 43% single family apartments and the rest were special

⁶ Excluding the greater Stockholm and the greater Goteborg

housing including elderly / disabled apartments, student apartments and other special housing units. The total multi-family stock with more than 2,3 million apartments has occupied about 179 million square meters of heated area, out of which, more than 77% were built before 1975 and are aged more than 40 years old today, (Energimyndigheten, 2015c; SCB, 2015d). Figure below, Figure 1-5, shows the distribution of multi-family apartments by their period of construction.

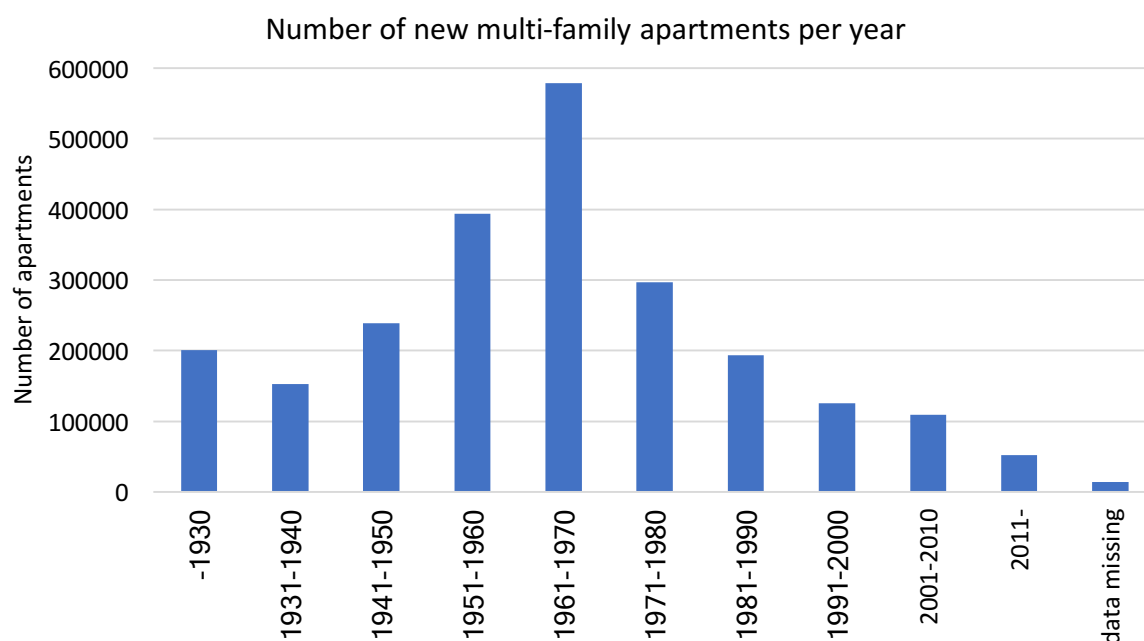


Figure 1-5: Number of apartments in multi-family building stock and period of construction, (SCB, 2015b)

Clearly the record years, 1960 – 1974, with around 940 000 apartments⁷ in multi-family buildings comprise the majority of the multi-family building stock, (SCB). Although as discussed earlier the million homes program was a great success in abolishing the housing shortage of 60s, due to its limited time frame and economic constraints, it came with major side effects.

Extensive housing construction during 60s in order to solve the housing situation led to the extension of bigger cities through formation of residential zones in suburban areas. To cope with the time limit, shortage of human resources and expensive construction works, large-scale industrialized construction, through standardization and prefabrication, was favoured which was also facilitated by the state support.

Buildings came to being with wide variety of forms. However, there were financial incentives to plan projects with 1000 or more apartments in similar buildings. Therefore,

⁷ Including 668 231 apartments in multi-family buildings from the million homes program, 1965-1974, SCB

about 50% of the multi-family apartments were built in a group of 10 or more of similar buildings, a quarter came in blocks of 4 to 9 buildings and the rest were constructed in smaller projects, (Hall & Viden, 2005). Architecture and planning of million homes programme were strongly influenced by the volume of construction. Pre-cast concrete became more common in construction of multi-family apartments yet most buildings used onsite-cast concrete. Blocks of buildings were formed in strict geometrical shapes with plain unpleasant facades with horizontal lines of windows or balconies using, among other materials, asbestos, glass and aluminium, (Björk, Nordling, & Reppen, 2012; Hall & Viden, 2005).

Despite the positive ambitious of million homes programme, shortcomings set the grounds for critics to become widespread mid-way the program and continued to grow strong in late 70s when the shortage of housing was replaced by surplus of apartments in unattractive locations. Most of the critics were associated with the external environment of the million areas which was most often given the least economic priority. Since most of the buildings were built in outskirts of the big cities, to provide stimulating living environment, the emergence of proper public transportation, local business services, day-care centres, schools and recreational facilities were imminent, which were left most often disregarded at the time, (Hall & Viden, 2005; Johansson, 2012; B. Roos & Gelotte, 2004).

It did not take long for those suburban areas to lose popularity. Due to infrastructural deficiencies, as mentioned earlier, residents who could afford to leave, chose central locations while in most cases no or very little improvements happened for the remaining inhabitants. Gradually, these areas became socio-economically segregated and a deprived social image was perceived by outsiders, (B. Roos & Gelotte, 2004). This distorted image affected the housing market to some great extent. What has happened afterward to the buildings from the million homes program, either abandoned, maintained, modernized, repurposed or demolished, was mainly influenced by the housing market. It was estimated that by the year 2012 about 830 000 apartments in multi-family buildings were left standing, from which about 600 000 were in need of extensive maintenance and renovation measures, (Hall & Viden, 2005; Johansson, 2012).

Since these buildings, at their 40s, are approaching the extent of their service lives, while the majority has not received proper care, they face serious technical issues which require urgent attention. Water and sewage installations mainly but also other components have reached/passed their service lives and need to be replaced. There is leakage problem in the ceilings, bathrooms have moisture problem, façades are damaged and ventilation and heating systems need thoughtful consideration. At the same time, according to the requirements of planning and building act (PBL), these buildings must adopt today's requirements and needs, (Dalenbäck & Mjörnell, 2011; Hall & Viden, 2005; Johansson, 2012; B. Roos & Gelotte, 2004; J. Roos, 2010).

Maintenance by itself include both actions which ensure the acceptable performance of respective components and actions that are carried out by the end of components' service lives in order to retain the original performance of the respective components, (replacements). In case of renovation, planning is more complicated and require more skills and expertise. For instance, to Improve the standard of the buildings, mainly to the same standard as in new buildings, alteration in the design, floor plan and the façade are required. On the other hand, every building has a unique design and is built using specific materials which limits the choice of techniques and the level of renovation. Furthermore, in some cases, buildings' architectural and heritage values impose extra limitations.

Considering the need for renovation in multi-family buildings of the record years during the past two decades, although very limited, investments in renovation has increased since 1997, (Bygginidustrier, 2015). Unfortunately, even at this very slow pace of investment, the important notion of energy efficiency has often been neglected in renovation planning. As stated earlier, residential buildings by the year 2014, use around 23% of the total energy supply in Sweden, (Energimyndigheten, 2015b). According to (Energimyndigheten, 2015a), the specific energy-use in multi-family buildings in Sweden has been reduced by 13% from 203 kWh/m² and year in 1995 to 176 kWh/m² and year (excluding household electricity⁸) in 2013.

As we know, due to the buildings' long service and economic⁹ life, buildings have long-term impact on the energy use. Besides, implementing energy efficiency measures in maintenance or renovation projects, decreases the costs of energy efficiency measures which helps the profitability of such investments. Now that many buildings are in need of extensive maintenance and renovation measures, the opportunity is presented for investment in energy efficiency measures at marginal costs. A large share of costs associated with implementation of energy efficiency measures are related to the required adjustments and alteration of the buildings' envelope. Upgrading windows, insulation, heating and ventilation systems, depending on the architecture and design of the building, often are cost- and labour-intensive. However, if studied carefully, costs related to such measures (changes in the building design and floor plans) are partly seen while planning for extensive maintenance and renovation. Installation of lift, upgrading the apartments, repairing the façade, attic and the basement and so on, imply changes in the design and the floor plan. There has been number of studies pointing out the economic advantage of combining energy efficiency and renovation measures for the property owners, (Dalenbäck & Mjörnell, 2011; Guler, Fung, Aydinalp, & Ugursal, 2001; Gustafsson & Karlsson, 1989; Liu, Moshfegh, Akander, & Cehlin, 2014; Tuomo & Juha-Matti, 2010). If this opportunity

⁸ 40kWh/m² and year schablon value

⁹ The service life is the expected lifetime of a product during which it offers acceptable performance. By the end of the product's service life it must be replaced. The economic life is the expected lifetime of a product during which it is useful (in economic terms) to the owner.

is missed, it will take long time until again a similar opportunity shows up. The question is what the obstacles are toward such investments and why despite all the efforts from the government, energy efficiency is still disregarded in renovation planning of multi-family buildings.

On the other hand, there is often concern about new technologies when considering energy efficiency measures. The problem with new developments and latest technologies (as is the case in other sectors) are often the high capital costs required and the high risks related to the performance and future running costs. However, as shown by (Dalenbäck & Mjörnell, 2011), the use of such technologies is not a necessity when a proper combination of currently utilised technologies can lead to high reductions in energy use.

Since savings in operation costs is the way, through which, an energy efficiency measure pays back the investment costs, the energy price and its future development play an important role in profitability of such investments. Another important factor in this regard is the current energy performance of a property, which is subject to energy efficiency investment. The lower the energy performance of the building, the better the profitability of energy efficiency investments. Bearing that in mind, the high energy use in multi-family buildings implies the huge potential for energy savings and better profitability of these investments. However, unfortunately the energy price development has not been in favour of energy investments. (Nässén & Holmberg, 2005; Nässén, Sprei, & Holmberg, 2008) argued that the low price of delivered energy has been a key barrier toward energy efficiency investments in Swedish residential housing sector. These studies illustrate the strong correlation between the energy use in residential buildings and the energy price implying that investments in energy efficiency measures demand relatively large increase in energy price. These results on profitability of energy efficiency investments highlight the importance of the current opportunity that allow investors to implement these measures at marginal costs.

Since profitability of an investment strongly influenced by the nature of investor's internal demands, the priorities and objectives of housing companies play an instrumental role in the extent of investments in energy efficiency measures. (Högberg et al., 2009) divided housing companies into three categories based on their ambitions toward energy efficiency and explained why these companies due to structural and financial differences do not deal with this problem equally. Besides, lack of knowledge, skills and expertise as discussed in (Hall & Viden, 2005; Johansson, 2012), which most often lead to high risks associated with investments in energy efficiency measures, further explain differences in methods used in different housing companies.

Regardless, energy efficiency measures are not limited to the technical improvements. Delivered energy in residential building is used either for services, heating purposes or by tenants for appliances inside apartments. The tenants' behaviour thus become quite

important when it is understood that it can directly influence the final energy use of their respective property. Here, the main problem is that to achieve such behavioural changes, beside general awareness about the benefits of the energy savings, require financial incentives.

The problem with lack of incentives amongst tenants in the Swedish housing sector lies within the rental agreements between the housing company and the tenants. Most often the energy costs are included in the rent., In such agreements, since tenants are not directly associated with energy costs, bearing in mind the very low share of energy costs in the rent, behavioural changes are less likely to happen in foreseeable future.

As briefly discussed, there are different factors affecting the profitability of energy efficiency investments thus the willingness towards it. On the other hand, buildings are usually different in design and application with different architectural, aesthetic or heritage values which makes planning for maintenance and renovation unique and specific to the respective property. These two limitations beside the financial and the socio-economic issues make planning for energy renovation quite complicated. That is why, the existing issues with renovation of multi-family buildings are yet to be overcome, even though there have long been discussions about it.

There are different approaches to maintenance and renovation, the choice of which have considerable effect on the owners, tenants and society as a whole. These issues which, are strongly affected by the characteristics of the Swedish housing market, will be discussed in detail in the coming chapters.

1.4. Aim and objective

The aim of this research project is to create a framework for strategic maintenance and renovation planning with regard to energy efficiency. In order to achieve this, a complete understating of the current housing situation is essential. Therefore, the objective of this thesis has been to study the current condition of multi-family buildings and develop a method that can be used to evaluate and improve maintenance and renovation strategies.

Accordingly, this thesis seeks to come upon and explore the following questions.

1. what role does the housing market play in the creation of the current situation?
2. What are the common maintenance strategies?
3. How can we devise a maintenance plan?
4. How renovation and energy efficiency can be systematically incorporated in a maintenance plan?
5. How does the choice of maintenance strategy affect both the housing company and the property?

1.5. Summary

The intention of this chapter has been to provide enough information so that the reader can get a general idea, however introductory, about the current status of maintenance and renovation in multi-family buildings in Sweden. The development of the multi-family building stock and the key factors affecting the level of investments in this sector has been studied. The national energy and climate policies were presented and difficulties towards energy efficiency investment were introduced and briefly discussed.

We understand that current technology can deliver enough energy reduction opportunities to meet national goals. However, lack of knowledge and skills and absence of a proper platform for strategic planning of maintenance and renovation, are important obstacles towards proper planning and utilization of such technologies. The opportunity presented today, due to the need for extensive maintenance and renovation measures in old multi-family building stock, must be seized and energy efficiency measures must be implemented.

As discussed briefly, there are different economic, social and technical issues affecting investments in energy renovation of multi-family buildings in Sweden. In order to overcome the difficulties in renovation planning, not only the effects of the operating environment (the housing market in this case) on each of these issues but their interactions and dynamics also need to be further studied. Therefore, in the following chapter, the Swedish housing market and its properties will be thoroughly studied and its effects on number of technical, social and financial issues will be discussed. Thereafter, opportunities in maintenance and renovation from different aspects of sustainability will be addressed. In the end, a method will be introduced which can facilitate systematic incorporation of renovation and energy efficiency in the maintenance planning process. Furthermore, different maintenance strategies will be introduced and their effects on both the economy of the housing companies and the service/economic life of the respective properties will be evaluated.

2. The research environment

As mentioned earlier, there is a need for renovation in multi-family building stock in Sweden. Buildings are old and in poor condition. Moreover, the low energy performance of these buildings is a problem if the national energy and climate goals are to be met. Even in a rather small share of multi-family building stock which has already been renovated, the energy-efficiency potentials have not been fully utilised. Clearly, there are difficulties in planning for maintenance, renovation and/or implementation of energy efficiency measures. Housing market characteristics, policies and subsidies besides economic constraints add up in creating a very complicated situation for decision makers.

In order to assess the claimed potential for energy savings in real estate sector, we need to study and understand the environment within which this potential inhabits. In this context, the Swedish housing market form the research environment and is what defines boundaries for this study.

To be able to fully understand and follow the following discussions first it is important to have a clear picture of what maintenance and renovation entail in this study. These terms are often defined differently in different standards and are used differently by different institutes/organizations.

2.1. Maintenance and renovation

The given definitions regarding maintenance and renovation are specific to this study and placed so that the results and the intended message can be conveyed clearly. The definition of these terms are important in understanding the differences between activities related to maintenance and renovation of multi-family buildings in Swedish rental housing market.

Different standard systems have different definition for the term “maintenance”. The European standard EN13306, (European Committee for Standardization, 2001), gives a broad classification for this term in which most operation and daily repair activities are included in the definition of maintenance. In the Swedish standard AFF04, however, maintenance is defined as actions aimed at restoring the old function of a managed item and is separated from operation and repair actions.

In this study, the Swedish standard definition is used for maintenance as costs related to repair are considered separately. It is important to note that repair actions are considered to be those actions that have not been planned for. These actions are required whenever a problem or a faulty item is reported in the system and are not related to the replacement of the respective item. Actions aimed at restoring the old function of a managed item, as defined for maintenance, include both planned actions during and by the end (replacement) of the item’s service life.

Extra measures with the aim to upgrade the building to a higher standard (a better utility value from users' perspective) is considered therefore as renovation. These actions can be for example: upgrading kitchen fixtures, bathroom and toilet fittings, floors, plan design, etc. Furthermore, the implementation of energy efficiency measures will be the definition for "energy-renovation". Such measures are for example: extra insulation for the walls, ground floor and attic, air-tightening of the building's envelope, new energy efficient windows, heat recovery, solar cells, etc. Therefore, costs related only to the energy- / renovation are considered as investment and those costs related to maintenance are considered only as costs.

2.2. The Swedish rental housing market

The main characteristic of the Swedish rental housing market is its rent control system. Generally, rent control systems are imposed in times of serious housing shortage (during the second World War in Sweden) to prevent profiteering. The aim basically is to provide everyone with standard and affordable housing opportunity. Imposing rent control on a housing market, however, affects different components of the market differently. The costs and benefits of such regulations have been studied in numerous theoretical as well as empirical studies, (Jenkins, 2009; Turner, 2003). Although the majority of scientists have been against such regulations, because of the strong political support, the rent control system has yet remained to be an important part of the Swedish housing policy. However, the current regulations are quite different comparing to the regulations introduced during the Second World War. These regulations have been adopted/softened during the past few decades based on the market condition, (Jenkins, 2009; Turner, 1988). Today, this system is a variation¹⁰ of second generation rent control, (Ellingsen & Englund, 2003), and is based on two important characteristics of the Swedish rental housing market: a rather large public rental sector and a well-established nation-wide tenants' association, (Turner, 1988).

The rent level in the Swedish rent control system is determined through negotiations between housing owners and the local tenants' association without the intervention from either the central government or the respective municipalities. The tenants' association is a national organization formed to protect the rights and interests of tenants. It was first introduced during 50s for apartments in municipal housing companies but later during 70s expanded to include the private landlords. With more than 500 000 member households, tenants' association holds strong and competent position in collective rent negotiations against housing owners.

The original rent control system didn't allow for changes in the rent. In contrary, the current system allows for rent increase under two conditions. The first condition refers to the annual property portfolio management costs of housing companies. In order to be able to cover

¹⁰ (Lind, 2001) categorized the rent control system in Sweden as type "E"

these costs, a housing company can request for an average rent increase and negotiate the total desired amount with the tenants' association. Upon agreement, the allowed excess can be distributed among the owner's housing stock based on internal priorities. The second condition refers to the utility value of the owner's selected apartments. In this case the owner can request a rent increase only if the standard (utility value) of the building has been improved.

In the assessment of the utility value, for the tenants' association it is important how the tenants value different components of the selected housing such as: location, building quality, benefits, management, size, layout, modernism, location, etc. In case of a granted permission, the rent increase imposed by the owner, according to the tenancy act, must be reasonable comparing to the established rent level (through collective negotiations) in a similar apartment owned by a municipal housing company, (Boverket, 2003; SABO, 2013c). However, it is important to note that, since the new rent is set based only on the utility value in a comparable apartment, it does not necessarily reflect the renovation costs, (Lind, 2015), and can be set at a level comparable to the new construction.

There are many issues believed to have roots in the existence of the rent control in a housing market, yet the complexity and interdependencies of such issues besides the diversity of rent control systems, resulted in ambiguous conclusions, (Jenkins, 2009). Such issues are for example: low rate of new construction, low maintenance activity, abandonment, reduced mobility in both housing and labour markets, segregation, changes in the type of tenure, creating black market, welfare losses, etc., (Arnott, 1995; Arnott & Shevyakhova, 2014; Basu & Emerson, 2000; Early, 2000; Glaeser, 2002; Gyourko & Linneman, 1990; Ho, 1992; Lind, 2015; Olsen, 1988; Turner, 2003).

In a market where the free-market rents depart quickly from the controlled level, the difference causes lock-in effect. This means that specially in attractive locations tenants tend to stay longer than they would in different market conditions even if their preferences change. In this situation, those tenants who manage to get the rent-controlled apartment benefit at the expense of new residents. Lock-in effect is more common in older buildings in attractive locations. Because of the characteristics of the rent setting system in Sweden, as mentioned earlier, older buildings which have not been renovated have significantly lower rent level than the free-market rents. The owners of such properties, in case of no renovation, can only negotiate the rent increase to compensate for the property's management costs while the free market rents are strongly influenced by changes in demand. Furthermore, since changes in demand do not affect the rent setting negotiations, the relationship between rent and location is very weak in Swedish rent regulation system. Hence, buildings' age become one of the important determinants in the Swedish rental housing market, (Borg & Song, 2015; Turner, 1988; Wilhelmsson, Andersson, & Klingborg, 2011). This situation has resulted in an inefficient allocation of housing. New tenants who are willing to pay more, are forced to choose less attractive areas or the more

expensive free-market apartments. In a number of studies, (Andersson & Söderberg, 2011; Arnott & Igarashi, 2000; Boverket, 2013a) substantial well-fare losses have been estimated because of the situation with miss-match and miss-allocation of rental housing in Sweden. In a broader perspective, Olsen (Olsen, 1972) concluded that, although the purpose of rent control is to distribute wealth equally amongst residents, because of such imperfections, the redistribution is highly random.

Furthermore, the lock-in effect lead to low housing and labour market mobility in the regulated rental housing stock. Tenants are reluctant to move even in case of receiving higher paid jobs in another city which means they are less inclined to react to changes in labour market, (Jenkins, 2009). On the other hand, as shown in a study in New York City (Gyourko & Linneman, 1990) the existence of regulated rental housing market induces mobility in prospective tenants who are willing to relocate in order to get access to cheaper regulated apartments. On other note, Arnott (Arnott, 1995) suggested that, less mobility in controlled apartments may as well be welfare-improving. He argued that since neither the owner nor the tenant in a free-market pay the full social costs of relocation, excessive mobility has negative effect on the social welfare. Also it should not be forgotten that the discussed low mobility in a regulated rental housing market can be less pronounced in an imperfect but real regulated rental housing market where black market sub-lettings can reduce the negative effects of immobility in regulated sector.

Here forward, the effects of rent control on number of important factors will be reviewed. The Swedish rent control system then will be discussed in each situation. The discussions here are necessary in order to understand the arguments in the following chapters.

2.2.1. Maintenance

In a rent control system where there is ceiling on the rent level, there are less incentives for the owners toward maintenance activities. As management costs increase in time beyond inflation, especially in markets where there is less competition for services in construction sector, it becomes difficult for housing owners to optimize their income. In such situations, typically maintenance activities are the ones to be sacrificed to cover uncontrollable costs which leads to faster deterioration of the properties, (Klingenberg & Brown, 2010).

Number of studies, (Gyourko & Linneman, 1990; Olsen, 1988), suggest that the low level of maintenance in such buildings, can be partially compensated for, by the increase of long-term tenants' self-maintenance activities. Long-term Tenants have incentives to carry on maintenance as the low monthly rent (comparing to free-market) leads to higher disposable income. It is important to mention that self-maintenance activities are often limited to the apartment level as major maintenance needs can be carried out either by the landlord or a group of long-term tenants. In a rent control system with vacancy decontrol (the landlord is allowed to increase the rent before the new tenant moves in), the level of maintenance however is strongly dependent on the owner's commitment in certain level of maintenance.

In such situations if the owner cannot guarantee, typically too little maintenance is carried out. Whereas, in a free-market, the owner would carry out reasonable maintenance activities in order to keep the rent on par with the market rent and the property value high, (Arnott & Shevyakhova, 2014; Glaeser, 2002; Gyourko & Linneman, 1990; Ho, 1992; Kutty, 1996; Olsen, 1988; Turner, 2003).

It should be noted that disregarding the type/existence of rent control system, the level of maintenance can be affected by some other factors. Composition of tenants and building's location are amongst such factors which can sometimes result in higher/lower maintenance in both controlled and free markets. For example, low-income families living in unattractive locations have less incentives toward self-maintenance. Another issue in less attractive locations is the over-crowding problem which causes faster deterioration. Therefore, maintenance in buildings in such locations needs more attention.

The situation in the Swedish rental housing market is however different. According to the Swedish tenancy act, costs of maintenance is included in the rent, thus the owner is responsible for sustaining the functionality of the property and as such, activities carried out to retain the original standard of the building does not qualify for rent increase during rent negotiations. However, as discussed earlier, landlords are allowed to negotiate a rent increase if the building has been upgraded to a higher standard (better utility value than the original). These issues, beside the subsidy scheme introduced in 1975 (Boverket, 2003) to promote modernization rather than maintenance, have resulted in reduced incentives for maintenance in the current market.

A large share of multi-family buildings is old and in need of extensive maintenance measures. For a landlord, since in any case his properties must go through maintenance, it might be profit-maximizing to postpone maintenance in order to renovate the buildings to higher standards so as to decontrol it, (Arnott, 1995; Lind, 2015). This phenomenon became a norm in attractive more central markets where the gap between free-market and controlled rents is rather large and there is high willingness to pay. furthermore, in less attractive suburban markets, this might still be a better alternative to maintenance.

Even though, by law, housing companies are not allowed to skip maintenance and let buildings deteriorate, there are areas where buildings have been left without care in a really bad condition. In such locations, under certain conditions it is somehow profitable for landlords to skip maintenance and let buildings deteriorate. Despite the low quality of buildings, these landlords charge tenants with relatively high rent¹¹. As suggested by Lind

¹¹ Rents are decided during negotiations between the landlord and the tenants' association on the basis of utility value. Once apartments deteriorate, the new rent can be discussed only if the tenants ask for it. In suburban areas where mainly low-income families live, tenants do not possess enough either incentives or power to initiate such negotiations. Read (Lind & Blomé, 2012) for more information.

(Lind & Blomé, 2012), high demand, housing allowance, overcrowding, illegal activities, etc., are amongst underlying factors which help creating such socio-economically deprived areas. As a result, unmaintained apartments in less attractive controlled markets, are more expensive than similar apartments in free-market. As indicated in the study by Lind (Lind, 2015), the current situation can lead to a shortage of low-quality low-rent apartments which is preferable to some low-income families.

The current rent structure, as mentioned above, creates incentives for building renovation rather than maintenance. In such system Lind (Lind, 2015) argues that eventually all the buildings in attractive locations where there is big difference between the market and controlled rents, will be renovated to higher standards. Those tenants with high location preferences won't be able to afford new rent levels and must relocate to an apartment with lower rent most realistically in a less attractive area. Instead prospective wealthier tenants will move in to apartments in more attractive locations. This situation in a long run will result in gentrification.

It should however be noted that, deterioration of rental apartments is a risk in saturated rental housing markets such as in bigger cities, whereas, in smaller cities, lower demand provides alternatives for tenants. In such locations, prospective tenants can find a properly maintained apartment in a free-market with more or less same rent as in controlled unmaintained apartment. This situation creates vacancy risk for housing owners in controlled market forming incentives for maintenance activities in buildings.

From the economic point of view, maintenance activities become a necessity after certain period in time when the rent income does not cover the operation and management costs. Not only maintenance activities reduce the operation costs, they prevent sharp reduction in property's market value. It is important to note that the short-term savings due to lack of maintenance does not compensate for the fall of property value, (will be discussed in the final chapter). Furthermore, the maintenance plans as discussed earlier, are affected by local housing market conditions. Therefore, housing companies, in the context of maintenance in rental apartments, can take on two different approaches. First: to maintain the apartments at certain point in time (depending on the specifics of the local rental housing market) in order to sustain the property market value as well as to optimize income. Second: to skip maintenance as long as there are tenants then either abandon/demolish or sell the property. For a company which decides to ignore maintenance in the expense of building deterioration, the long term plan as discussed by Lind (Lind & Blomé, 2012) could be that the housing company may be able to sell the property with a higher price than the real market value. Or that managers did not invest their money in the property thus don't care about the selling price. In this case, they see the company's bankruptcy as an exit door.

2.2.2. Building energy performance

Energy efficiency measures become profitable after a certain period in time both in free and controlled markets. The payback time is highly dependent on the energy price and the rent structure. If Landlords cannot adjust the rent to optimize the income based on investment, clearly there will be much less incentives toward such investments.

In Swedish rent structure, most energy efficiency measures do not qualify for rent increase since such measures (e.g. improved indoor air quality, lower electricity and heating use, more efficient insulation and so on) are not considered as utility value. As discussed by Lind (Lind, 2012), costs are the deciding determinants during rent setting negotiations. Since energy efficiency measures reduce the operating costs for the landlord, despite providing better indoor environment for the tenants, the landlord might even have to settle for a lower rent level. Therefore, for as long as rent levels do not represent the important characteristics of the building, there will be no added incentive for the owner toward energy efficiency measures.

2.2.3. Housing availability

One problem with rent regulation systems is that in the presence of such systems housing prices do not fully represent the dynamics of the housing market, (Lind, 2003). Since rents are controlled for, it is not clear if there is demand for higher rents in the market which eliminates profitable investment opportunities. This lack of information beside uncertainties regarding the future of regulation system, increase the risk for investors, which with a growing population translates to rental housing shortage in long term, (Jenkins, 2009). Moreover, it is not surprising that in a market where free-market rents surpass controlled market rents, conversion activities increase. Navarro (Navarro, 1985) mentioned that in such situations sometimes owners prefer to demolish rental apartments in order to construct condominiums. Therefore, not only there will be less construction of rental apartments, a share of existing rental apartments will be as well converted to condominiums.

In Swedish system of rent control, however, in central more attractive locations, rents in new constructions can be negotiated at relatively high price considering the gap between the controlled and the free market rents. This creates incentives for housing companies toward construction of new rental apartments, however the problem with attractive locations is that there is not so much free space left for new construction. In contrast, in less attractive locations where there is free land to use, the gap is fairly small and in some areas the rent level is even below the marginal construction costs. This situation reduces incentives for housing companies toward construction of new rental apartments in such locations, (Hackner & Nyberg, 2000). On the other hand, as mentioned in previous chapter, property tax reforms of 1990 and mid 20s have strongly encouraged home-ownership in Sweden, (Stenkula, 2014). Improved wealth increased the demand for home ownership specially in central locations thus shifting construction activities toward construction of condominiums.

The characteristics of Swedish rent regulation system, however, imply that such effects on new construction of rental apartment would to a large extent still exist even in the absence of rent control. In the absence of the control system, especially in central locations, condominiums would still be preferable both for the households and the housing companies in terms of subsidies and lower risk of investments. In such locations, construction of new rental apartments would follow more or less the same trend as in the controlled market since in the Swedish control system there is room for higher rent levels in new and renovated apartments. The situation would be the same for less attractive locations with relatively high demand (close to bigger cities). Whereas, in less attractive locations where the demand is low, the construction is not profitable irrespective of the control system in force. It should be noted that, in case of high demand, changes in demand can concentrate vacancies on new construction if there are apartments in the vicinity with lower controlled rent levels, (Lind, 2003).

The effects of rent control system on new construction and availability of rental apartments discussed above can shed light on a previously mentioned issue regarding the geographical distribution of rental apartments during 1990s, Figure 1-4. As mentioned before, the rate of new construction of rental apartments did not follow changes in geographical demands creating long waiting lists in bigger cities whereas high rate of vacancy became a huge problem in smaller cities. Wilhelmsson (Wilhelmsson et al., 2011) argued that one main reason behind such deficiency has been the existence of rent control system. Rents could not be set to reflect the true costs of construction unless subsidized, therefore there was low incentive for production of rental apartments in bigger cities. In smaller cities, shift in demand caused high vacancy rates which considerably decreased income for housing companies creating incentives toward abandoning/demolishing of rental apartments.

2.2.4. Segregation

One of the main goals of rent-control system has always been to provide standard and affordable housing for everyone. That even low-income families can have the opportunity to live in attractive more central areas of the bigger cities. As mentioned above, in Swedish rental housing market, in attractive areas, there is tendency toward renovation and conversion rather than maintenance and construction of new rental apartments, respectively. The imminent rent increase in central rental apartments after renovation will force low-income families to move to cheaper apartments (less attractive areas). This situation in a long run will result in increased segregation despite positive intentions of rent control system in Sweden, (Glaeser, 2002).

2.3. Considerations

One important assumption made in this study is that the rent control system in Sweden will be effective for foreseeable future. As Lind (Lind, 2015) mentioned, there are no major

oppositions to the current regulation system. Although there have been few minor changes in the regulation for private owners, the rent control system continues to have strong support from the government.

The Million Homes Programme apartments constitute the majority of troublesome apartments from which more than 70% are rental units. These apartments, are well spread throughout the country, either in suburban areas or attractive central locations. Besides, due to their unique characteristics, these apartments represent high level of complexity in planning for maintenance and energy-renovation. In the following chapters, discussions will be made around rental multi-family apartments from Million Homes Programme. Nonetheless, results from this study are not limited to such apartments and can be applied (with considerations) to all apartments with different type of tenure.

In the following chapters all major problems and complications (opportunities in a sense) affecting the energy-renovation planning process of rental multi-family buildings in Sweden will be discussed. So far, considering the housing market conditions in Sweden, we know that such problems are of multi-disciplinary characteristics. Therefore, in the beginning of next chapter, to understand the basic underlying principles for each parameter, we try to review the issues separately disregarding the interactions among technical, social and financial aspects. In the end, the relationships among these parameters will be studied and different ways they affect each other will be clarified.

3. Opportunities for maintenance, renovation and energy efficiency

In the previous chapter, the research environment (the Swedish housing market) was addressed and its effects on number of issues (i.e. maintenance, renovation, energy efficiency, housing availability, segregation, etc.) were discussed. The knowledge gained from previous chapters can help understanding the dynamics of the following discussions. In this chapter actions (opportunities in hand) needed to improve the current condition of multi-family buildings will be discussed. The existing technical, financial and social issues will be reviewed and their effect on decision making for either maintenance or renovation will be discussed.

3.1. Technical aspects

To understand what the technical problems are the current operation and maintenance condition in multi-family buildings should be studied. As have already been mentioned for number of times, maintenance has been neglected in a large share of the multi-family buildings from the record years. The situation began with the changes in the rent structure from the rent ceiling approach to the utility value system in 1975, (Boverket, 2003). The effects of oil crisis on prices and wages, particularly in the construction sector, did not entirely reflect on the rent level. As a result, to decrease costs and optimise income, housing companies reduced the level of maintenance. On the other hand, Inadequate maintenance may be the result of low rental income due to a lower demand and increasing number of vacant apartments. As discussed earlier, there has been a serious geographical imbalance in the housing market more noticeably after 1990. The smaller cities and communes where there have been excess housing and vacant apartments has often been the areas where construction was most intense during the late 80s and the early 90s. And where there is a surplus of housing, it is difficult to economically justify maintenance expenditures. The renting difficulty however is not limited to smaller cities and can happen in bigger cities as well. This phenomenon can be observed in socially segregated areas in bigger cities. Social segregation means that some parts of the housing stock are less attractive than others due to social factors and preferences and is often tied with residents' economic advantages. This means that it can be more difficult to rent or sell apartments in such locations which in turn means lower incentives to pay for maintenance costs.

During the years 1979 - 1980 the government issued a temporary provision to allow state loans for maintenance costs particularly aimed at apartments from Million Homes Programme. the purpose was to better distribute standard housing and stabilize the housing market by avoiding sharp rent increase due to renovation practices, (Boverket, 2003).

In 1982, the survey to review the maintenance condition of rental and condominium properties, (SOU-1982:65, n.d.), conducted by SABO (Swedish Association of Municipal

Housing Companies), reported that most SABO companies had to reduce maintenance to lower level than SABO maintenance standards due to financial difficulties.

The maintenance problem beside the economic downturn and increased unemployment during the early 80s, led to introduction of ROT-programme (Ds-Bo, 1983) (a ten year renewal and maintenance programme with the focus on unemployment and market stabilization). One important goal of this programme was to improve maintenance while preventing unnecessary radical alterations. However, this goal was strongly challenged by other objectives of ROT-programme such as: modernization, apartment composition, energy efficiency, availability, equality and integration and above all the better use of construction market capacity (in order to maintain the employment in the construction sector). The ROT-programme was limited in scopes already in 1988 when the government's attention once again shifted toward new construction. At this time, as discussed in previous chapters, deregulated credit market and heavily subsidized interests were starting points for the early 90s housing crisis.

in 1992 the government decided to replace the former loan and interest rate premiums on new construction and renovation with a system where new financings happen in the public credit market. The purpose was among other things to gradually reduce government subsidies for housing construction. The high cost of construction limited radical renovation practice during 90s. in 1993 the government introduced tax reductions for the cost of labour in repairs, maintenance, renovation and extension work, (Regeringen, 2008b). The reduction was limited to the labour costs and did not include the costs of material. The main purpose was to increase resource utilization and temporary boost employment in the construction sector.

In Sweden, building construction, maintenance and renovation should be carried out according to PBL (Planning and Building Act) and BVL (Act on Technical Requirements for Construction Works, etc.). Buildings' interior should be maintained to preserve essential technical characteristics such as: resistance, fire, hygiene, health, environment, usage, energy conservation, insulation and accessibility. In maintenance a careful attention must be given to buildings' value from historical, cultural, environmental, and artistic point of view as well as the surrounding nature. These considerations in some cases can mean that in order to preserve values, the technical requirements might need to be adjusted. These requirements have been changed and improved during recent years, and there is therefore a large number of buildings that do not meet the requirements of today's building regulations.

As discussed before, maintenance has been reduced, neglected or postponed due to financial difficulties, (Muyingo & Lind, 2009). The problem however is that under-maintenance cannot be noticed by authorities unless reported by tenants. Maintenance activities do not need to be reported as construction work therefore there cannot be a proper picture of how and to what level maintenance has been carried out.

National Housing Board in many occasions has noted that maintenance is often neglected in residential buildings which is related to the housing situation (Boverket, 2003). In the Swedish housing market, because of financial difficulties, the maintenance practice is very dependent on individuals' motivation and skills. Most often maintenance measures are postponed to be covered in major renovation projects. SABO (Boverket, 2003) reported that about 50% to 80% of the costs of a renovation project may be on measures that must be attributed to maintenance.

As mentioned, the maintenance practice is very dependent on owners' motivation and skills. These factors beside the financial status of the owner, determine the type and level of maintenance activities carried out. Maintenance itself based on its purpose is most often divided into two main categories, (SS-EN 13306, 2010)): the preventive (planned) maintenance and the corrective maintenance. This structure applies to both European standard (EN13306) and the Swedish standard (AFF04). The corrective maintenance is a classical failure based maintenance policy where the faulty operation (or breakdown) of a component defines the time and level of action required. On the other hand, preventive (planned) maintenance is a policy designed to prevent failure. In both categories, sometimes when a failure happens and a component needs immediate attention, the owner can seize the opportunity and combine this activity with other maintenance needs (either postponed or planned in near future) to save costs. The maintenance activities carried out in this form are called opportunistic maintenance.

In this study, actions carried out under corrective maintenance strategy are considered maintenance costs only if they are related to the replacement costs of the respective parts. Other corrective costs are assumed to be the repair expenditures. This applies to the preventive maintenance strategy too. In this strategy, all the costs apart from those that are planned and the replacement costs are considered as repair expenditures.

Both maintenance approaches (preventive or corrective) come with certain deficiencies depending on which, building owners can justify their selection. In corrective maintenance one important issue is how malfunctioning of a part will affect both tenants comfort and other parts in the system. In such policy, errors and failures are reported when observed. It is important to note that some parts' failures are not visible unless they are in severe condition. This lag can imply higher unexpected costs. Also in such systems, the owner must be capable of providing maintenance service on a short notice. Otherwise, delayed maintenance in the expense of tenants' comfort, can increase the cost of activity. Preventive maintenance, on the other hand, reduces the risk of failure while maintaining the high efficiency of the system (building). Since in this system maintenance activities are planned, there is less risk of delayed maintenance. The preventive maintenance needs proper monitoring of the building in order to create appropriate maintenance plan otherwise improper observation can result in unnecessary maintenance activities. Besides, monitoring

changes in the housing market is of quite importance. Planning for maintenance therefore is tied tightly with information about future possible changes. It is cost-efficient for a housing company to postpone maintenance if demand drops, policies change, new subsidies will be introduced or more cost-efficient methods and technologies surface. Considering all these uncertainties beside, possible changes in financial situation of housing companies, unexpected maintenance costs or opportunistic maintenance activities (to combine two or more activities at the time when a failure happens in order to reduce future costs) make planning for maintenance activities difficult and costly (in terms of time and skills), (for more information, read (Lind & Muyingo, 2012; Shohet, Puterman, & Gilboa, 2002)).

In Sweden, corrective maintenance policy comprise a large share of maintenance activities, (Muyingo & Lind, 2009). According to Boverket (Boverket, 2003), the municipal housing companies seem to apply preventive maintenance policy more than in private housing companies nonetheless interestingly, private companies run more yearly inspections. However, these plans because of aforementioned uncertainties are not followed as expected, (Muyingo & Lind, 2009). The private companies tend to use corrective maintenance policy while considering renovation as a part of renovation projects. These results however are extracted from 100 sample housing companies and therefore does not represent the whole multi-family building stock.

the urgent need for maintenance in multi-family buildings from the record years corresponds not only to deferred maintenance activities but also to the fact that some (mainly costly) measures just have reached the end of their service life. Table below (Table 3-1) shows some of the items with longer life cycle, which are most likely to be in need of immediate renovation measures, (SABO, 2013b). It is important to note that these numbers correspond to the time intervals between each replacement. Shorter time interval plans exist for maintenance activities neglecting of which result in shorter service life than mentioned below and consequently higher costs.

Table 3-1. Service life for different items in multi-family buildings according to (SABO, 2013b)

Measures	Service life in years
Piping (water and sewage)	
Piping – Horizontal	50
Piping – Vertical	50
Façade & balconies	40-50
Windows	50-60
Wooden floors	40
Ceilings	40
Doors	30
Toilet & bathroom fittings	30
Kitchen fixtures	40
Stairwells	40
Common laundry room	30
Attic insulation	50
District heating centre	30

Heating distribution system including vents	50
Air handling units	30
Air distribution system	30-50
Electricity distribution system and instruments	30
Lightings	25-30
Elevators	30-40

Since there is no registry for maintenance activities as mentioned earlier, it is difficult to estimate the number of apartments in need of extensive maintenance and renovation measures. Today there are over 800 000 apartments left from the record years of apartment buildings. SABO in 2009 estimated that over 300 000 apartments, only in municipal housings were in need of maintenance and renovation measures while the rate of maintenance and renovation reported was about 11000 apartments per year, (Boverket, 2014). This number was about 600 000 apartments for all types of ownership in multi-family buildings which were reported to be in need of maintenance and renovation measures, (Johansson, 2012). These buildings often have a combination of technical and social problems. Neglected maintenance often happened in less attractive areas where number of vacant apartments was high and high relocation strengthened the effects of socio-economic segregation.

The use of new construction methods and materials besides insufficient supervision and maintenance led to early technical defects in apartment buildings. Water and sewage piping is one costly measure which in almost all aforementioned buildings has reached its service life and need to be replaced. The load specially on bathrooms has increased significantly in recent decades because of new habits and more importantly overcrowding in bigger cities, (Boverket, 2003). One other quite costly measure is the elevator. From 1977 according to PBF (planning and building regulation) all buildings with more than two floors need to have elevators installed. Also in special buildings elevator is needed for elderlies and for people with special needs. Not only there are many buildings with no elevators but also there are many elevators installed but in need of security and safety adjustments. Installation of elevators is one of the activities which requires alteration in a building's inner design. If no elevator is installed and there is no extra space for it, an outdoor elevator sometimes is an option which in this case immediate attention must be given to the building's architectural and cultural values. Damaged façade and ceiling and rotten windows frame are also amongst common costly deficiencies. One important notion to be considered carefully is the use of hazardous materials in façades and roofs which may be present in large number of buildings. As (BOOM) states: facades can be covered with asbestos sheets or have joints with PCBs between concrete or around windows and doors. Roofs can be covered with tiles of asbestos cement. The works of these materials poses special demands on occupational safety and disposal of waste.

According to SABO, some measures have the highest possibility of having been neglected by housing companies. These measures are: plumbing, windows and roofs. Negligence of

such measures have much higher probability in areas with lower demand and higher vacancy rate. Therefore, SABO companies have a good idea of what kind of maintenance will be needed in the coming years.

Also it is important to note that the highest maintenance costs related to costly measures in multi-family buildings will come at about 30-50 years of age. To meet such maintenance needs, a maintenance plan with a proper timeline is required so that the housing company can specify budget for upcoming maintenance costs. This plan (predictive maintenance plan) needs to be updated continuously based on complete building performance as well as changes in the housing market. Despite the need and importance of proper maintenance planning, a sizable number of housing companies either do not have maintenance plans or do not follow the plans. These companies consider the effort for preparing a proper maintenance plan to be extensive comparing to the need. Also the fact that an unexpected corrective maintenance can change the whole plan, adds to its difficulties. In general, lack of knowledge, skills and resources are behind the under-development of maintenance planning in multi-family buildings in Sweden, (Boverket, 2003).

Multi-family buildings require extensive maintenance and renovation measures approximately every 40-50 years to meet requirements and demands. However, this time span is independent from the energy performance requirements. Current specific energy use requirements (BBR) for different climate zones are between 75-125 kWh/(m²_{Atemp}·year) (Boverket, 2015b) comparing to the national average of 176 kWh/(m²_{Atemp}·year) in 2013¹², (Energimyndigheten, 2015a). The current requirements are set for new constructions but also apply to renovation measures with changed layouts. In renovation with smaller scales, requirements only apply to the affected parts of the building, (Boverket, 2015b). According to PBL, if in a renovation project, achieving BBR requirements are unreasonable, there are five requirements which instead should be met. These requirements are formulated as demands on U-values (specific heating capacity) for roofs, walls, floors, windows and exterior doors.

The low rate of new construction besides lacks of incentives toward implementation of energy efficiency measures in maintenance and renovation plans make achieving the national energy and climate goals for 2020 and 2050 very difficult if possible at all. As mentioned earlier the best opportunity to implement energy efficiency measures show up when there is already a need for extensive maintenance and renovation measures. Maintaining and renovating roofs, walls and windows having energy efficiency in mind potentially saves a lot of time and money. The additional cost for implementation of such measures is then lower. It is important to remember that the energy renovation of a building most often create a better indoor climate.

¹² Excluding the household electricity use (40kWh/m² and year presumption value)

As mentioned earlier, construction methods and materials used during the Million Homes Programme era, lack of proper maintenance and the deteriorating nature of buildings itself have put these buildings in current condition. Boverket (Boverket, 2010) reports that almost two third of heat losses in multi-family buildings happen through exterior walls and windows; three out of five apartments does not fulfil minimum hygiene air flow requirements of 0,35 l/(m².s); and last but not least, the mechanical ventilation with no heat recovery dominates which corresponds to 9TWh/year loss of energy.

Statistics from the energy agency (Energimyndigheten, 2015a) shows that by the year 2013, the specific energy use has been decreased by about 12% and 20% comparing to the level in 2003 in multi-family and single family buildings respectively. This difference could be explained by the little effect of energy cost on tenants in rental multi-family buildings as energy costs are included in the rent and therefore energy efficiency is not valued as a quality in such buildings. On the other hand, tenants in single family houses are more responsive toward changes in energy price as changes in energy efficiency results in economic gains indicating higher price elasticity, (Nässén & Holmberg, 2005; Nässén et al., 2008). This is an incentive for tenants to implement energy efficiency measures and adjust energy use behaviour.

Based on the results from BETSI (Energy performance of buildings, technical status and indoor environment), measures which correspond to highest energy saving potentials in multi-family buildings are given below. Moreover, current national guidelines are given to point out the existing potential for energy savings through implementation of energy efficiency measures in maintenance and renovation.

- Energy source

When assuming a boundary for buildings, energy sources often fall out of the boundary. The reason could be that users are restricted in access thus adjustments in the energy supply system is not an option. Therefore, improvements are made to the items within the boundary. Number of these adjustments are given below. However, one way to take control over the supply system is to switch from a network connected system (such as district heating) to the available free energy sources. One important notion with the switch is that by free energy source it is meant that the source of energy is free such as: wind; solar; geothermal¹³ and so on, not exploiting the source. For example, to take advantage of free geothermal energy, a ground source heat pump could be used, the use of which requires, besides the capital investment, electricity for its operation. However, considering both the coefficient of performance (COP) for commercial heat pumps and the free heat source, the use of heat pumps is economically justified. According to the

¹³ Shallow geothermal resources

results published from 40 pilot studies in implementation of energy efficiency measures “Halvera mera”, (Högdal, 2013a, 2013b), the use of geothermal can potentially result in 53 (kWh/m².year) savings on average on delivered energy.

- Buildings’ envelope:

- Walls, roof and basement floor

As mentioned earlier a great deal of energy is lost through the damaged exterior walls of the record years’ buildings. Therefore, to limit the heat transfer and improve the energy performance, additional insulation need to be installed on the exterior walls, roof and the basement floor. According to Boverket (Boverket, 2010) the average U value (heat transfer coefficient) for the exterior walls of multi-family buildings from the record years is about 0,4 W/(m².K), while the U value in current BBR requirements is 0,18 W/(m².K). The difference presents a potential for energy savings through additional insulation of exterior walls. According to the results published in “Halvera mera”, insulation of façades and roofs can potentially result in 9 kWh/(m².year) and 6 kWh/(m².year) energy savings on average, respectively. With current technology achieving low U values are possible however it is important to note that cost-efficient low U values correspond to higher thickness which can become problematic specially in buildings with cultural heritage values. The same issues apply to roofs and basement floors, proper insulation of which can reduce heat losses up to great extent.

The exterior walls in multi-family buildings need extra attention in case of maintenance and renovation. The façade in these buildings usually have aesthetic values representing specific characteristics of the record years. Mainly uniformity and the use of horizontal lines and sharp colours to signify the identity of the area and the main objectives of extensive construction during the record years being the equality and fairness. On the other hand, almost all multi-family buildings from the record years were occupied with balconies making them an important characteristic of the façade. Therefore, during planning for maintenance and renovation not only the materials used but also the design and formations must be considered carefully.

- Windows and doors:

Windows influence the energy performance of buildings to a great extent. Improper choice of windows can facilitate heat loss and cause a lot of discomfort for the residents. In a cold climate such as in Sweden, efficient windows with high thermal resistance (low U value) play an important role in the quality of the indoor air as well as building’s energy performance. Unfortunately, windows in record years’ buildings are in no good shape

today. These windows often came with large glasses where the surface is divided into a larger and a smaller part, where the small part was intended for airing purposes. According to Boverket (Boverket, 2010) heat losses through windows are 30% higher on average than losses through exterior walls. The average reported U value for the windows in multi-family buildings from the record years is around 2,3 W/(m².K) while the current requirement according to BBR is 1,2 W/(m².K). Considering the significant improvement in the energy performance of windows nowadays and the availability of such efficient windows, the old, less efficient windows must be replaced with new energy efficient alternatives. Results from the “Halvera mera” shows a huge energy saving potential in replacement of windows. According to this study 16 kWh/(m².year) on average can be saved only by replacing inefficient windows. However, windows can also have significant cultural values and they should not be changed unless there are exceptional reasons. In case of replacement in special situations, materials, proportions, grading and profiling must be well adapted to the original character. Otherwise, other measures should be taken to increase heat resistance.

The situation with doors is somehow less noticeable, since the heat transfer area for the outer doors in multi-family buildings is not comparable to the surface area of the windows. The average reported U value for the doors in multi-family buildings from the record years is 1,7 W/(m².K) while the current requirement after renovation according to BBR is 1,2 W/(m².K).

- Ventilation system:

The majority of multi-family buildings from the record years use the simple mechanical ventilation system with an exhaust fan (F type). In such system the fresh air is supplied through vents and openings. The fresh air therefore is not treated and the quality is not guaranteed. Since the control is limited, the least hygiene air exchange cannot be guaranteed. Moreover, the heated exhaust air is expelled to the environment through which huge amount of energy is lost. The use of exhaust heat recovery system is very limited and often found only in renovated buildings. Exhaust heat recovery systems come in two forms: FTX (Från- och tilluft värmeväxlare) and FVP (Frånluftvärmepump). In the FTX system the heat in exhaust air is used to preheat the supply air. The technology for so-called FTX system has been developed for a long time. Heat recovery rate is currently at around 80 percent, sometimes even over 90 percent. In the FVP system, heat in the exhaust air is used as the heat source for the heat pump then transferred to either preheat the supply air, the tap water or the water in hydronic heating system.

In case of renovation, the FTX system is more suitable for existing buildings with

FT (från- och tilluft) type of ventilation system. FT system is very similar to F system with the addition of supply fans. Therefore, the supply air is provided through the supply fans instead of vents and openings used in the F system. FTX system requires both supply and exhaust distribution system to be able to provide heat transfer as well as treated supply air. If the existing building is equipped with the F system, the construction work required to install the supply distribution system is quite expensive. The FTX system therefore is the best candidate in case of an upgrade from the FT system for better energy performance. However, it should be noted that in some cases where the supply and exhaust distribution systems do not meet at proper location, it can still cost a lot of money to install the FTX system.

On the other hand, the FVP system does not necessarily require the supply distribution system. The recovered heat in this case can be used for heating the tap water or the water in hydronic heating system. The FVP system takes less space comparing to FTX system. The FVP system can also be used the whole year round even when there is no space heating demand while the FTX system cannot bring any benefit during summer. However, it is important to mention that the FVP system uses substantially higher electricity (the electricity use in compressor) to run comparing to the FTX system.

The other system which is used mainly in older multi-family building is the natural ventilation system. During renovation, depending on the characteristics of the building, either FTX or FVP can be used for a better energy performance. Also it should be mentioned that neither F, FT nor natural ventilation systems can provide proper indoor air quality and therefore need to be replaced by other available alternatives. results from “Halvera mera” study shows the importance of ventilation system in energy performance of multi-family buildings. According to these results, FVP and FTX ventilation systems can contribute to 39 kWh/(m².year) and 34 kWh/(m².year) energy savings on average, respectively.

- **Lighting:**

Lighting is another area through which significant savings can occur. Not only the light bulbs used during the record years were not efficient but also the control systems were often inefficient if available at all. Today, light bulbs and lighting systems have been developed and have significantly lower energy consumption than before. LED lighting can be combined with presence control to reduce electricity use by up to 90 percent, (Boverket, 2003).

All the measures mentioned above have noticeable effects on energy performance of multi-family buildings in Sweden. However, implementation of such measures during renovation has not received proper attention. As Boverket (Boverket, 2013b) reports, only between the

years 2001-2011 the share of mentioned energy efficiency measures in renovation of multi-family buildings are as follows:

- Heat recovery through ventilation has been installed in about 4%;
- Additional insulation of the buildings' envelope has been added to Less than 8%;
- Windows have been replaced by energy-efficient alternatives in Less than 10% of all renovation projects in multi-family buildings.

One issue with energy efficiency measures is that often cost-efficient measures are the inexpensive measures. This means that more comprehensive measures that offer better energy savings are costly and are hard to financially justify. However, to achieve national climate and energy goals of 2020 and 2050, implementation of low cost energy efficiency measures is not enough, (IVA, 2012).

Windows need to be upgraded or replaced with more efficient alternatives; ventilation systems need to be modernized for both better indoor climate and efficient heat recovery; and buildings' envelope need to be repaired, tightened and insulated to reduce heat losses. These measures are usually not profitable if implemented only for energy saving purposes. Yet, if such measures are carried out when renovation of façade, windows and ventilation system is a necessity, the profitability of energy efficiency measures are calculated only for the marginal costs of these measures.

As discussed earlier, implementation of energy efficiency measures in different renovation projects vary among housing owners. Technical skills and expertise, financial support and motivation toward sustainability are three most important elements involved in decision making for energy efficiency investments, (Boverket, 2013b; Dalenbäck, 2005; IEA, 2008; IVA, 2012; Mattson-Linnala, 2009). Lack of each element can change the profitability of energy efficiency investments in renovation projects.

3.2. Financial aspects

3.2.1. The negligence of maintenance

One reason behind the negligence of maintenance measures mainly in weaker housing markets (less attractive areas) has been the difficulty, housing owners face in income optimization. High costs of operation with regard to low rental income has forced landlords to decrease the level and frequency of maintenance measures. This negligence, however a temporary solution at time, resulted in bigger problems later on.

A single building in theory has a certain service life the length of which is defined by its deterioration rate. The service life is a period of time during which a product operates with a reasonable failure rate. The expected service life of a product is calculated based on maintainability and reliability of the product, (Ebeling C. E., An Introduction to Reliability

and Maintainability Engineering, McGraw-Hill Companies, Inc., Boston 1997). Therefore, operational condition and maintenance activities can affect the service life of different parts in the building. As age and wear take their toll on the product, In the late life of the product, the failure rate increases leading to higher repair and maintenance costs.

For a housing company with sizable building stock of different ages, uneven distribution of maintenance costs can possibly be flattened in the whole stock. Whereas, in a smaller company with limited stock, the situation is rather different as its difficult to flatten costs when there is a limited inventory. It should also be noted that multi-family buildings from the Million Homes Programme comprise a great share of the profile in some of the largest municipal housing companies. This make it quite difficult to optimize maintenance costs even in companies with large building stock.

The issue with uneven distribution of maintenance costs became more important during and after mid-90s when municipal housing companies could no longer make reservation for future maintenance costs from untaxed earnings. This problem has encouraged the frequent negligence of preventive maintenance measures in multi-family buildings in municipal housing companies, (Boverket, 2003). This negligence can lead to destruction of capital by means of lost market value and increased operation and maintenance costs.

3.2.2. Structural differences within housing companies

Companies with weak economy who could not optimize income decided to postpone maintenance. These companies operate mainly in difficult housing markets with socio-economic problems. The components have reached their service life and are inefficient both from operational and financial perspectives. After more than 40 years, today these buildings are in need of extensive maintenance measures. Obviously housing companies who couldn't manage maintaining their properties before are not able to finance major maintenance projects today. According to Mattson (Mattson-Linnala, 2009) these companies own about 17% of the multi-family buildings with the urgent need for renovation measures from the record years.

Next are companies with balanced economy who were able to optimize their income. These companies either operate in moderate housing markets or have their building stock distributed in strong, moderate and weak markets. In such situations often deficiencies from the weaker markets are eliminated by the surplus from the stronger markets. Depending on companies' internal strategy, they could both carry out proper maintenance or postpone maintenance and combine maintenance measures with major renovation activities. In these companies, maintenance has often been prioritized in stronger markets and postponed in weaker housing markets. Thus financial problems arose while planning for major renovation projects. Such companies manage about 52% of the multi-family buildings with the urgent need for renovation measures from the record years, (Mattson-Linnala, 2009).

On the other hand, there exist number of companies with proper economy operating in strong housing markets, (or have the majority of their building stock in strong markets). Since the economy in such companies is strong, the level of maintenance and renovation can be decided depending on internal interests. These companies own about 31% of the multi-family buildings with urgent need for renovation measures from the record years , (Mattson-Linnala, 2009).

The existence of notably different housing markets suggests huge differences in the level and orientation of maintenance and renovation measures. Piled up inevitable maintenance measures are economically difficult to justify. Often, renovation is realized as the best solution. However, considering the fact that renovation's profitability is quite location sensitive, (Lind, 2015), this solution cannot be applied to all housing markets thus not suitable for all housing companies. For example, in a deprived housing market with socio-economic problems, increase in rent can result in higher vacancy. The extra income from higher rents often cannot compensate the income deficit because of higher vacancy. For a housing company with strong economy and broad portfolio, rent increase in attractive markets can compensate for the costs of renovation in deprived locations. The situation is completely different for a housing company with weak economy operating only in less attractive areas. Therefore, every maintenance or renovation plan are devised based on individuals' economic condition, internal interests and the characteristics of the local housing markets.

3.2.3. Finance and economy

Knowing that every building requires individual action plan, it is important for a housing company to have a good knowledge of what the alternatives are and how they should be valued. Ultimately, it is the housing company who decides which option to take on, the decision of which is mainly based on financial and economic grounds. Some of the possibilities that are often considered when there is a need for an action plan are as follows:

- To maintain the property
- To renovate the property
- To demolish/repurpose/reconstruct the property

As given above there are different action plans to take on, the choice of each brings unlike financial burden for the housing company. In the end it will be the housing company who decides which plan is suitable and what needs to be done. After a careful economic evaluation of alternative opportunities has been made, a project plan is considered and resources are allocated accordingly. In this chapter the important terms and determinants affecting the financial situation of housing companies and the methods used to evaluate each, are presented and discussed. The advantages and disadvantages of each alternative are then examined and discussed in the final chapter. The understanding of terms and the use of methods given in this chapter are essential for future analysis.

The market value of a property

The market value, according to the international valuation standard IVSC, is defined as: “the estimated amount for which an asset or liability should exchange on the valuation date between a willing buyer and a willing seller in an arm’s length transaction, after proper marketing and where the parties had each acted knowledgeably, prudently and without compulsion.”

Since the market value of a property plays an important role in the financial performance of a housing company, it is necessary to study how this value is obtained. There are different methods using which a housing company can estimate the market value of its property.

Two commonly used methods for estimation of the market value for a chosen property are, (Peterson 2002):

- **Sales comparison method (SCM):**

This method is used where a current market exists for similar properties. In this method pricing is based on comparison between similar properties that have been traded in the market over a given period of time. Comparison can be made using different units depending on available data such as, (Appraisal institute, 2001): market value per square meter; gross capitalization factor (market value divided by the gross rent income) and purchase price coefficient (market value divided by taxable value).

This method due to its limitations is meant to be a baseline for evaluation not a perfect indicator of the market value. Therefore, the longer the period during which samples have been selected, the more reliable the estimated market value becomes. Besides, the generic nature of the SCM method ignores the uniqueness of every property which must be considered while using this method. Finally, the crucial issue with the use of the SCM method is that, for certain type of properties such as rental properties, as Hungria (Hungria-Garcia, 2004) mentioned, it is difficult to find enough samples since rental properties are not traded as frequently as other types are.

- **Income method**

The income method is based on the relationship between the yield (capitalization rate) in a certain market and the net operating income (NOI) that a property produces. This method is used to estimate the value of income-producing properties such as rental multi-family buildings. The capitalization rate is the investor’s rate of return. The market value in this method can be estimated using two approaches choice of which depends on the available data and the required

- Capitalization method

the income capitalization method is simple and based on both the NOI for the first year and the yield (capitalization rate). The yield can be estimated from observations on the market by considering a typical investor's required rate of return for a property of the similar type and class. The market value then can be calculated using the following equation, (Appraisal institute, 2001):

$$\text{Market value} = NOI_1/Y_o = NOI_1/(p - g) \quad \text{Eq. 3-1}$$

where,

NOI_1 = normalized net operating income during the first year;

Y_o = initial yield;

p = internal rate of return;

g = prognostic value in percentage for changes in either the value or the yield in future.

- Discounting cash flow (DCF) method

The DCF method is more complex than the Capitalization method and requires more data. In this method, the sum of the present value of the NOI during a chosen period is added to the present salvage (exit) value of a property to estimate the current market value of the property. The market value then can be calculated as, (Appraisal institute, 2001):

$$\text{Market value} = \sum_{t=1}^n (NOI_t / (1 + r)^t) + S_n / (1 + r)^n \quad \text{Eq. 3-2}$$

where,

$$S_n = \frac{NOI_{n+1}}{Y_n}$$

where,

NOI_t = net operating income during year t ;

S_n = salvage value by the end of the year n ;

r = the discount rate;

t = time variable;

n = analysis period;

Y_n = Yield by the end of the year n .

As it can be seen, the accuracy of the market value obtained from the DCF method relies heavily on the accuracy of important variables; the discount

rate and the yield.

In the estimation of the exit yield as Hungria (Hungria, 2004) states, important attention must be paid to the location, expected market trends and the property's economic life.

As mentioned above, in estimation of the market value there are number of factors which need to be taken in to consideration. Since every property is unique, its specific characteristic are important determinants in estimation of its market value. These determinants are for example: location, size, age, rent, NOI, etc.

Considering the level of uncertainties in estimation of the market value of a property, the use of both methods is suggested in order avoid mistakes. Also, it is valuable to calculate the book value of the property in order to make sure that the estimated market value lies within reasonable boundaries. The book value of a property is the value of the property according to its financial statements and is calculated as follows, (Berk, 2014):

$$BV_t = BV_o - D_t - L_t \quad \text{Eq. 3-3}$$

where,

BV_t = book value at year t ;
 BV_o = initial book value;
 D_t = total depreciation at year t ;
 L_t = total liabilities at year t ;
 t = the year of analysis.

The capital expenditures in this equation is the initial book value of the property when the financial statements were written and can be the purchase costs, construction costs or remodelling costs, etc. In calculation of the book value, the capital expenditures and liabilities are fixed values while the depreciation can be set differently by different companies.

Depreciation

Depreciation indicates the decrease in the value of a property over time hence a method to distribute the capital costs of the property over its economic life¹⁴, (Hendrickson, 2008). The value of a property is dependent on its overall condition and the housing market it operates in, (Nordlund, 2010). The overall condition of a property is determined based on its performance and age which can be improved using maintenance and renovation. The influence of the housing market however due to its nature is inevitable. The effect can be

¹⁴ In economic literature usually economic life is defined as that is the time that you expect it to be economically viable to operate the asset, (Nordlund, 2010)

positive or negative. It relates to factors surrounding the property such as: unbalanced supply and demand and/or the attractiveness of its location.

Depreciation is a measure of the value of a property in a certain time period. However, it should be noted that, depreciation is a non-cash flow used to optimize the financial statements. Depreciation is a process through which a housing company allocates the costs of buying and/or improving a property over the duration of its economic life. Rather than taking a large deduction in the year the investment is made on a property, using depreciation, the smaller deductions are made over the property's economic life. Therefore, depreciation plays an important role in the income statements¹⁵ of a housing company and the book value¹⁶ of its properties. For a given property, the method used to calculate depreciation expenses and the estimated salvage value are important factors, proper choice of which can help housing companies produce desired financial statements.

Considering depreciation, both the real net operating income and the net operating income stated in the income statement can be calculated as, (Hendrickson, 2008):

$$NOI_{e,t} = (R + I) - (O + M + T + G + A) - d_t \quad \text{Eq. 3-4}$$

$$NOI'_{e,t} = NOI_{e,t} - z(NOI_{e,t}) \quad \text{Eq. 3-5}$$

$$C_t = C_{e,t} - z(C_{e,t}) + d_t \quad \text{Eq. 3-6}$$

where,

$C_{e,t}$ = the NOI written in the income statement for the year t ;

R	= Rental income;
I	= interest subsidies;
O	= operation costs;
M	= maintenance costs;
T	= property tax;
G	= land costs;
A	= Administration costs.

$C'_{e,t}$ = the after tax NOI written in the income statement for the year t ;

C_t = the real NOI for the year t ;

z = marginal corporate income tax;

¹⁵ An income statement is a financial statement that measures a company's financial performance by its net income over a specific accounting period, (Berk & Demarzo, 2014).

¹⁶ Book value is the cost of a property minus its accumulated depreciation, (Berk & Demarzo, 2014).

d_t = depreciation expense for the year t ;
 t = the year of analysis.

Since the total amount of depreciation during a property's economic life is dependent on the property's value at the time of investment and its estimated salvage value, changes in property's value imply changes in the amount of depreciation. New depreciation values should be assigned to either a renovated or a newly purchased property. In both cases the respective salvage values should be estimated. The choice of the salvage value can be based on the financial performance of the housing company. For example, a company with good economy could assume the salvage value of a newly purchased property to be zero in order to decrease its total tax liabilities.

Once the total depreciation value is set, its expenses can be spread over the asset's economic life using various methods, the choice of which affects the real cash flow as well as the income statements of the company. In any case, as mentioned in the Swedish annual account act (ÅRL), the annual report should be established in accordance with generally accepted accounting principles and give a true and fair view of the company's results and financial position, (Årsredovisningslagen, 1995:1554). Three common depreciation methods are:

I. Straight-line depreciation method

One simple method to calculate the depreciation expenses is the straight-line depreciation method. In this method, housing companies estimate the salvage value of a property at the end of its economic life, then allocate the difference between the salvage value and the property's cost, uniformly in its economic life.

$$d_t = (BV_o - S)/n \quad \text{Eq. 3-7}$$

where,

d_t = depreciation for the year t ;
 BV_o = initial book value (capital expenditures);
 S = Salvage value;
 n = estimated economic life;
 t = the year of analysis.

The straight-line is the simplest method which is commonly used and offers a flat rate for depreciation during the whole economic life for an asset. The problem with this method is that it does not offer flexibility for adjustment in tax liabilities. The amount of depreciation during the early years when the maintenance costs are lowest is the same as the amount toward the end of asset's economic life when maintenance costs are highest. To fix this issue and be able to charge higher depreciation expenses during early years accelerated depreciation methods can be used.

II. Declining balance depreciation method

The declining balance method is an accelerated depreciation method which produces a decreasing depreciation expense over the economic life of an asset. There are two ways one can calculate the depreciation rate in this method.

The first option is to double the straight-line depreciation rate and apply it to the un-depreciated amount in the first and subsequent years. In this way, the salvage value of the asset is not considered in estimation of the depreciation rate. Therefore, the depreciation should be ceased when either the salvage value or the asset's economic life is reached. The second option on the other hand offers an exact value for the depreciation rate so that it allows for complete depreciation by the end of asset's economic life. For this method, the depreciation rate can be calculated as:

$$r_d = 1 - \sqrt[n]{\frac{S}{BV_o}}$$

where,

- r_d = depreciation rate;
- BV_o = initial book value (capital expenditures);
- S = Salvage value;
- n = estimated economic life.

therefore, the depreciation expense is obtained using the following equation:

$$d_t = \begin{cases} r_d(BV_o - \sum_{i=t}^{t+g} d_{i-1}) & , g \neq n \\ BV_o - \sum_{i=t}^{t+g} d_{i-1} & , g = n \end{cases} \quad \text{Eq. 3-8}$$

where,

- d_t = depreciation for the year t ;
- r_d = depreciation rate;
- BV_o = initial book value (capital expenditures);
- S = Salvage value;
- t = the year of analysis;
- g = age of property at the year of analysis;
- i = time variable.

III. Sum-of-year method (SYD)

The SYD method is another accelerated depreciation method. Similar to the declining balance method, depreciation is accelerated during early periods when maintenance costs are lower which allows for higher tax reductions in early years. Depreciation expenses using the SYD method are obtained using the following equation:

$$d_t = (BV_o - S) (n - (g - 1)) / (n + 1) \left(\frac{n}{2}\right) \quad \text{Eq. 3-9}$$

where,

- d_t = depreciation for the year t ;
- BV_o = initial book value (capital expenditures);
- S = Salvage value;
- n = estimated economic life;
- t = the year of analysis;
- g = age of the property at the year of analysis.

One issue with depreciation as defined above is that it's based on the assumption that buildings are a single object with certain deterioration rate. Therefore, these methods only give us a rough estimation of how a building's value changes during its estimated economic life. In reality, buildings consist of many different parts with different respective deterioration rates. The parts with shorter service lives are replaced earlier than the building's estimated economic life while the effect of the new parts are not considered in the depreciation value.

In the context of renovation and retrofit, as discussed earlier, only those measures which improve the standard of a property comparing to its original standard, are considered as investments thus can be considered as capital expenditures. Changes in capital expenditures imply changes in the total depreciation value. These costs can be spread over the economic life of the property. On the other hand, measures carried out to maintain and sustain the performance of the property, are considered as maintenance costs and are to be expensed immediately during the year they have been carried out. The difficulties in allocation of costs to either renovation or investment are therefore forthcoming in renovation projects where a good share of the total costs belong to deferred maintenance measures. The problem is more evident when the new market value of a property needs to be established after improvements has only been made to one part of the property, (Nordlund, 2010).

One way to deal with this issue is to use the new NOI after retrofitting project and evaluate it against the NOI of the property in its original condition. In this approach, the income market valuation method is utilized where the NOI of the property and the corresponding yield define its market value. Therefore, changes in the NOI can define the share of costs spent on standard improving measures in a renovation project. Referring to the example given by Mattson (Mattson-Linnala, 2009), if a 5000 Kr/m² renovation cost results in 200 Kr/m² changes in the NOI comparing to the original NOI, the composition of costs will be:

$$\Delta BV = (NOI_r - NOI_o) / Y_r = 3333 \text{ Kr/m}^2$$

where; ΔBV , is the increase in property's value which corresponds to the share of investment spent on standard improving measures (the share of the total costs that can be depreciated); Y_r , is the proper yield for the location at which the property operates, in percentage; NOI_r , is the NOI after renovation project and NOI_o , is the original NOI of the property.

As it is shown in this example, 3333 Kr/m², is the value added to the property. However, in obtaining this value there have been number of assumptions, changes in which will result in different evaluation of the property. Yield and NOI are values identified based on assumptions made based on amongst all, the market condition and its behaviour in the future. These assumptions have already been discussed and their importance have been stressed, therefore should be carefully observed.

To avoid such uncertainties another approach to depreciation and cost allocation has been proposed, the proper use of which can result in better evaluation of assets' value and allocation of costs in maintenance and renovation projects.

Component accounting (depreciation)

The component accounting approach to depreciation (component depreciation) is an approach according which different parts of a property are individually depreciated at respective rates. Since 2012, component depreciation has been regulated in the accounting standards board BFNAR 2012:1 and is currently being used by a number of housing companies in Sweden. One of the advantageous of this approach is that, each component is depreciated individually. In contrary to the traditional approach, the reference point for performance evaluation is the time immediately before the replacement has been made. therefore, both renovation and replacements qualify as capital expenditures and respective costs can be depreciated over the component's economic life.

According to K-3 regulations, (Komponentsredovisning, SABO), the use of component depreciation should not change the amount of total tax deductions, but provide a more systematic approach to depreciation of assets, (multi-family buildings in this case). One of the disadvantages of the component depreciation method is its complexity specially during transition from the traditional methods.

The difficulties in the transition arise when the total depreciation need to be broken down to appropriate depreciate expense for each component. The depreciation expenses for each component can be calculated using similar depreciation methods mentioned earlier (only the straight-line method in the case of Swedish regulations). Depending on the quantity and quality of the data available for each component (part), there are three groups of housing owners for whom alternative methods to facilitate transition from traditional to the component approach are suggested, (SABO, 2013a).

- I. For companies with a complete record of all parts in the asset registry.
For such companies, use of component depreciation approach is quite straight forward and the book value of the property can be distributed among components according to the cost and economic life of each component.
- II. For companies with no such registry but a maintenance plan.
For such companies, the maintenance plan can be used in order to specify the depreciation expense for each and every component. In such method, components which are to be replaced in near future (according to the maintenance plan) will bear lower depreciation expense comparing to those components with long remaining economic life. In this case, when a component is planned/needed to be replaced, the remaining depreciation is eliminated and the new depreciation expense based on new costs of replacement should be calculated.
- III. For companies with neither such registry nor maintenance plan.
For such companies the depreciation expense should be assigned with respect to the type and shape of the property. In this situation, a weighted depreciation percentage should be calculated based upon which the book value is distributed among different components.

3.2.4. The economic evaluation of investment opportunities

In economic evaluations of different investment opportunities, each opportunity is represented by its cash flow profiles over the years or periods of the planning horizon. These interest periods are normally assumed to be in years. The net annual cash flow (net operating income, NOI) is defined as the annual revenues in excess of the annual costs.

The profitability of an investment thus is evaluated based on changes in net operating income (NOI) over the considered period of time. For a housing company, the NOI is mainly the difference between rental income and the operation and maintenance costs.

A housing company can increase the net operating income of its properties both by decreasing the operation and maintenance costs and/or improving the rental income. As explained before, a rent increase can be negotiated for renovation projects since the building standard is subject to change. In case of maintenance on the other hand, rent increase cannot be negotiated and the cost of capital should be compensated for through decreased operation and maintenance costs. To evaluate if the changes in the NOI can actually justify the cost of capital, housing companies take on different approaches depending on their internal agenda.

Capital budgeting methods

Most common capital budgeting methods used to evaluate the viability of different investment opportunities in housing companies are¹⁷:

I. Payback period (PP):

Payback period (PP) is a simple method to calculate the number of years by the end of which the initial investment is paid off, (Berk & Demarzo, 2014).

$$\text{Payback period (PP)} = A + B/C$$

where,

A = last period with a negative cumulative cash flow;

B = absolute value of cumulative cash flow at the end of the period A ;

C = cash flow during the period after A .

There are however two problems with the PP method:

1. It only considers the payback period but not afterward which means it does not measure profitability
2. It ignores the effect of time on the value of future cash flows

To counter the second problem with PP method, an alternative method called discounted payback period (DPP) can be used. In this method the time value of money is accounted for by discounting the future cash inflows of the project.

$$\text{Discounted Payback period (DPP)} = A' + B'/C'$$

where,

A' = last period with a negative discounted cumulative cash flow;

B' = absolute value of discounted cumulative cash flow at the end of the period A' ;

C' = discounted cash flow during the period after A' .

To calculate the discounted cash inflow for each period the formula below is to be used:

$$\text{Discounted cash inflow} = \text{Actual cash inflow} / (1 + r)^t$$

where,

r = the discount rate;

¹⁷ Although as (Hastig, n.d.) mentioned, some housing companies use internally developed capital budgeting methods.

t = the period of which the cash inflow relates to.

II. Net Present Value (NPV):

The NPV is a method to aggregate the present value of future cash flows associated with an investment that are spread over a number of time periods against the present value of the investment costs, (Berk & Demarzo, 2014). Therefore, a positive NPV indicates the profitability of an investment.

Net Present Value (NPV) = Eq. 3-10

$$\frac{S}{(1+r)^n} + \sum_{t=1}^n \frac{NOI_t}{(1+r)^t} - \sum_{t=0}^{n-1} \frac{C_o}{(1+r)^t}$$

where,

$$NOI_t = (R + I) - (O + M + T + G + A)$$

where,

NOI_t = net cash inflow (net operating income) during period t ;

R = Rental income;

I = interest subsidies;

O = operation costs;

M = maintenance costs;

T = property tax;

G = land costs;

A = Administration costs.

C_o = capital expenditures;

S = Salvage value;

r = discount rate;

t = time variable;

n = analysis period.

The NPV method is inherently complex and requires number of assumptions, accuracy of which has considerable effects on its calculation outcome. Besides, one important issue to be studied carefully is that the NPV method cannot be used to prioritize different investment opportunities since higher NPV could be due to higher investment costs than the efficiency of the investment. In Such situations profitability index (PI) is used together with the NPV method. The PI is simply the present value of future cash inflows divided by the investment cost. Higher PI value indicates the higher efficiency of an investment.

Considering the complexity of the NPV method sometimes Internal Rate of Return (IRR) is used to evaluate profitability of different investment opportunities. The

IRR is a discount rate at which the NPV of the future cash flows is equal to zero. To obtain the IRR, the NPV is set to zero and the equation is solved for the discount rate “ r ” which in this case is IRR. If the obtained IRR is greater than the cost of capital, the investment is considered profitable.

The IRR method is a simple way to evaluate different investment opportunities however, its simplicity results in number of restrictions. One important issue regarding the IRR method is that it cannot be used to evaluate investments with different lengths. For example, a high IRR from a short-term investment can have lower NPV comparing to a long-term investment with lower IRR. This means that the IRR method does not determine the size of investment in different opportunities. Therefore, it is suggested that the IRR method is used together with the NPV method to give a complete picture of the profitability and the added value of different investment opportunities.

The discount rate

As it can be seen in the previous equations, the discount rate is a crucial part of all capital budgeting methods, which determines whether an investment opportunity is worthwhile from the viewpoint of the company. The discount rate takes into account not just the time value of money, but also the risk or uncertainties involved in future cash flows.

Investments in housing markets are often long-term and are highly dependent on the market condition, which result in a risk premium or higher desired profit. The discount rate required by housing companies then should be adjusted so that it includes the risk and uncertainties of future cash flows. Therefore, a risk-adjusted discount rate can be shown as follows, (Berk & Demarzo, 2014):

$$r = r_f + r_p$$

and is calculated as:

$$1 + r = (1 + r_f)(1 + r_p)$$

where,

r = risk-adjusted discount rate;

r_f = interest rate on risk-free assets;

r_p = risk premium.

The risk-free rate is usually a ten-year risk-free rate offered as a combination of government bonds and treasury bills which are risk-free assets. Then r_p is the risk premium reflecting adjustments for the rate of return of the perceived risk in an investment opportunity over a specific time period.

The discount rates mentioned above indicate the rate at which the money will grow if invested for a certain period of time and are called real discount rates. However, these discount rates do not reflect the rate of growth of purchasing power due to inflation. The adjusted discount rate for inflation is called the nominal discount rate and is calculated as:

$$1 + r = (1 + r_r)(1 + i)$$

$$1 + r_r = (1 + r_f)(1 + r_p)$$

therefore,

$$1 + r = (1 + r_f)(1 + r_p)(1 + i)$$

where,

r = nominal discount rate;

r_r = real discount rate;

i = inflation.

It should be mentioned that both real and nominal discount rates can be used in investment profitability evaluation, however It is important to note that if the nominal value is used all future cash flows must be adjusted to the inflation and vice versa, (Berk & Demarzo, 2014). Therefore, in case of using inflation adjusted values, the NPV would become:

$$\text{Net Present Value (NPV)} = \frac{S(1+i)^n}{(1+r)^n} + \sum_{t=1}^n \frac{NOI_t(1+i)^t}{(1+r)^t} - \sum_{t=0}^{n-1} \frac{C_o(1+i)^t}{(1+r)^t}$$

considering the structure of the discount rates, estimation of a suitable discount rate value requires proper assessment of future market behaviours. as Hungria (Hungria-Garcia, 2004) mentioned, a proper discount rate should accommodate the target yield during investment period. In that regard, historical yield rates from comparable transactions should be studied to be able to forecast future changes. Since properties are complex assets, depending on the objectives, different discount rates can be fixed for different elements of the property. Although this would give investors a more precise evaluation of investment opportunities, it could potentially complicate the already complicated evaluation procedure.

Moreover, another important factor affecting the discount rate of an investment opportunity is the source of financing for the investment. For a housing company there are two different ways to finance an investment opportunity. Either using the equity (self-financing) or the debt capital (loan). The debt capital financing means that the owner borrows money from a bank which in this case banks are usually willing to put out loans equivalent to 60 to 85

percent of the property value, the level of which depends on the market condition and risks involved in the investment, (Mattson-Linnala, 2009). Size of the self-financed share of investment capital can affect the discount rate required for the investment opportunity and change the profitability outcome. In theory, for a credit company, the required rate of return is, (Boverket, 2015c):

$$\text{required rate of return} = \text{credit costs} + \text{administrative costs} + \text{risks}$$

for a credit company, risks involved in an investment opportunity are assessed, the results of which may affect the total costs of interest on the loan. For this assessment in the first place the housing company must convince the credit company that the investment opportunity is profitable. Both the assumptions and calculations made by the housing company will be assessed by the creditor. The important finding for the creditor is the potential of the resulting cash flows to pay back the required interest and the credit. Moreover, the creditor makes an assessment to explore the ability of the housing company to pay back the credit. This assessment is independent of the investment outcome and is based on the housing company's cash flow stability.

As explained by Boverket, (Boverket, 2015c), the interference of state can facilitate investments in renovation by two means. First, the introduction of state-funded loans which can potentially reduce the costs of credit for housing companies. The proposal means that the government lends money to credit companies, who in return can provide credits for housing companies with lower rate of return. Second, by providing support for housing companies in terms of credit guarantee. In this way the government will guarantee a certain percentage of losses in the investment to creditors which in return should result in lower assessed risk by the creditors.

Renovation and retrofit projects require high investment costs. In many cases the need to finance part of a renovation with the help of loans is imminent. Credit guarantees and State loans as mentioned above are financial instruments that can accelerate the low rate of renovation and renovation practices. Today there is an opportunity, considering the historically low market interest rates which allow for more profitable investments with the low cost of debt capital, to promote development in the multi-family building stock.

As discussed before, today there is a need for extensive maintenance measures in the majority of multi-family buildings from the record years. Considering the difficulties in financing such measures beside the demand for modernization in the stock, renovation is considered a financially sustainable option. On the other hand, this situation has created a great opportunity for implementation of sustainable measures during renovation both in terms of society (considering the existence of deprived socio-economically segregated residential areas) and environment (the low energy performance of multi-family buildings is considered a serious barrier toward national energy and climate goals). However, the

structural differences within housing companies in the Swedish heterogeneous housing market has resulted in unlike approaches toward sustainability.

In financial evaluation of investment opportunities all the changes are measured in monetary terms. Therefore, important measures which are not presented in monetary terms are often left out. Examples of such measures are: social benefits, gains and losses; safety and security improvements; environmental efforts and so on, (Byman & Jernelius, 2012). And that is a big issue nowadays to be able to put all those costs in the context of profitability in company level. In a holistic renovation project, not taking social benefits and losses into account would change the results and eliminates incentives for social development efforts in prospective renovation investments.

3.3. Social aspects

Considering the length of renovation and retrofitting process in multi-family buildings beside the long service life of buildings and the continuous effect they have on society, it is of quite importance that the social effects are considered and studied carefully. A well-functioning and diverse range of good housing promotes economic growth, labour market mobility and facilitates the integration of society.

Here in this section some of the important social issues resulted by renovation and retrofitting projects are reviewed. These issues can be divided into different categories as follows:

- Relocation of tenants
- Social segregation
- Tenants role in renovation and retrofit

3.3.1. Relocation of tenants

Since renovating a multi-family building is economically more desirable than maintenance, considering the profitability problems of extensive maintenance measures, most housing companies who can fund such investments take on the renovation approach. The main reason to carry out renovation instead of maintenance, beside the demand for higher standards, is the benefits gained from the potential rent increase.

The benefit of rent increase is however more pronounced in attractive locations where the gap between market and controlled rents are relatively large and there is willingness to pay among tenants. The situation is rather more complex in less attractive areas with socio-economic condition. Unfortunately, the majority of multi-family buildings built during 1965-1974 are located in such deprived areas where tenants' composition comprises a larger share with higher rental price sensitivity, (Mattson-Linnala, 2009).

The tenants with high price sensitivity are the economically vulnerable tenants who live on the margin. A larger share of such tenants, in case of renovation and subsequent rent increase, either can't afford to move back to the renovated apartments or cannot justify the value of the apartment with higher rent therefore decide to move out.

Being economically vulnerable, there are two groups of tenants between which there is a distinctive difference. The group of tenants who receive social welfare and housing aid and the group of tenants whose income is just above the threshold to be eligible for housing aid. For the first group, either these tenants decide to move or stay in the renovated apartment, changes in the rental costs can be compensated for by the extra housing aid received. This means that extra costs of increased rents fall upon the society. In case these tenants have already been receiving the maximum possible housing aid, the extra housing costs probably will impose changes in social welfare received. As for the second group, these tenants are already living on the margin. This group of tenants do not qualify for housing aid, they are the most vulnerable toward changes in housing costs.

This situation creates problems not only for the vulnerable tenants but also for the housing companies as the risk for higher vacancy rates increases with higher rate of tenants moving out. This problem is more evident in deprived areas as the degraded picture of the area perceived by outsiders makes it more difficult for the housing companies to attract new tenants with better economy. In more attractive locations, because of higher demand the vacancy risk is much lower.

The increased rents which result in higher property value, not only forces vulnerable tenants to move out but also causes displacement of small local businesses. This phenomenon in long term leads to gentrification of the area.

According to a recent study, (Boverkett, 2014), share of tenants moving out of their apartments during renovation projects has been around 90% higher than the movement in un-renovated properties. This share is about 115% for those tenants with higher price sensitivity. these values represent the magnitude of the vacancy risks involved in renovation projects specially in deprived areas. As for the tenants who move out, they often end up in an apartment with similar rent or lower rent than the expected rent in the renovated apartment. This could mean that these tenants move from renovated apartments to apartments which will be renovated in near future. Such relocation for tenants means similar housing costs (if not higher) plus the current and potential relocation costs. These transaction costs are relatively higher if the target groups to move are families with children with strong location preferences. Finding proper accommodation with reasonable costs are more difficult for such families. Moreover, there are necessities to be taken into consideration for children, such as: development, education, childcare, safety, health, etc. the accommodation and the security it provides, beside the safety and the security of the area are some of the factors affecting child's development, (Barnombudsmannen &

Kronofogden, 2011). As reported by Boverket (Boverket, 2014), many of the families are forced to move to either temporary or smaller accommodation which results in overcrowding and can have considerable effect on health and well-being of children. Besides, the relocation negatively affects the development and school performance of children, (Rädda barnen, 2013).

3.3.2. Social segregation

Social segregation can form as a result of class or economic differences. Considering the costs of construction and services, low income in such locations often is compensated by neglected maintenance. Since a large share of multi-family buildings from the million homes programme reside in so called deprived areas, for housing companies operating in such locations, the focus with extensive maintenance and renovation projects should be also on improving the socio-economic status of these areas.

The current housing shortage beside the low rate of new construction, affordable rental housing in particular, (Boverket, 2013a; Lind, 2015), forces the economically vulnerable tenants to choose from less attractive areas with socio-economic problems, which in one way or another results in increased segregation, (Boverket, 2015a). This has resulted in a formation of population in which residential areas become more homogeneous yet more heterogeneous between different districts. This development has been noticed in Million Homes Programme areas as early as 25 years ago, characterised by an over-representation of immigrants and low-income families. This has negatively affected the overall status of Million Homes Programme areas, (B. Roos & Gelotte, 2004).

Along with strong influx of people (Sweden has the highest number of refugee per capita), (OCED, 2015), the existence of the controlled rental market, allocation of rental apartments and low rate of new construction, segregation is to grow in the future. The increasing number of immigrants and refugees who already have integration problem (lack of knowledge in Swedish language) will result in segregated, over populated low status areas. Overcrowded housing is one of the major problems in Miljonprogrammet areas where number of occupants has negatively affected the wear and tear of apartments. Integration is one of the biggest concerns among swedes.

3.3.3. Tenants role in renovation and retrofit

The property owner can have different incentives in the choice of action to take on when the property requires immediate attention. Since the economy of an investment is often given the highest priority, renovation becomes the ultimate option. The level of renovation and standard improvement determine changes in the rent. This level is decided based on number of factors but mainly the economy. New rents are fixed in order to optimize income however sometimes to alter the tenants' composition. This means that the new rents are

fixed to attract a different type of tenants (mainly the type with better financial situation) while indirectly forcing existing tenants to move out.

The problem here is that those tenants whose apartments face remodelling and standard improvement has little power in affecting the renovation process or its outcome, thus the opportunity to remain in their apartments. As expressed by Westin (Westin, 2011), negotiations between the owner and the tenants is in reality a negotiation between a professional group (housing company) and an amateur group (tenants). Housing companies tend to show that tenants can actually get involved, negotiate and influence the level and to some extent details of renovation plans. While in reality the tenants' representative mostly gets to weight in for insignificant actions, i.e., the colour of tiles. Information and discussions on price tags are often denied. Even in cases in which tenants invested a lot of time and energy in negotiations, housing companies often did what they wanted anyway. This problem becomes more central knowing that the tenants' association in such conflicts often vote in favour of housing companies. Even if that's not the case, rent tribunal often can't stop renovation plans neither, (Lind, 2015; Westin, 2011).

3.4. Summary

Since the formation, the record years' suburbs have been developing a unique culture in a specific environment influenced by an ethnic mix of population. For many people, such areas are a reminder of memories and history. However, for outsiders, despite the gradual development in these areas, the image is still the image that was drawn during the expansion period. A physical environment as a breeding ground for segregation and crime, but also an exotic location, represented by exciting food and a new culture, (B. Roos & Gelotte, 2004). An image which is not entirely wrong. As much as those positive characteristics attract outsiders and promote life style, unemployment and crime have created an environment at which even many local residents feel unsafe. Overcrowding in these areas besides lack of proper maintenance have caused faster deterioration of multi-family buildings which have increased the need for extensive maintenance measures.

In the past, comprehensive renovation and remodelling of multi-family buildings in the million homes areas, most often led to social disparities through increased rents and displacements of local businesses. Today, considering the current condition of housing and the immediate need for extensive maintenance measures, a proper plan is to be devised to not only ensure the economic sustainability of the investment but also the social sustainability of the outcome both in terms of tenants' relocation and the attractiveness and accessibility of the area.

In order to achieve this, before all, housing companies and property owners need to improves skills, refine techniques and develop suitable methods in maintenance and renovation planning. On the other hand, the government can play an important role in sustainable development of Million Homes areas. This may be accomplished by eliminating

barriers and adjusting regulations or creating incentives to support investments in social sustainability, (which are not presented in monetary terms).

Considering the importance of these issues and difficulties reviewed in this chapter, one would realize the complexity involved in decision making for maintenance and renovation practices. Technical deficiencies are not to be ignored; energy performance needs to be improved; financial constraints should be overcome and social sustainability appears as a necessity. Therefore, maintenance/renovation plans are required to address these issues, the balance of which depend strongly on owners' knowledge and skills, financial status and motives.

4. Method

The technical issues regarding maintenance, renovation and energy efficiency were discussed in the previous chapter. Considering that the building types, construction techniques, architecture, materials and installations are known, the maintenance, renovation and energy efficiency measures and their respective implementation techniques are already well identified. Therefore, the difficulty is not of technical but financial nature as bigger housing companies with enough liquidity run extensive energy renovation projects with no technical constraints.

These financial problems however exist for both the housing companies and the tenants. Housing companies on one hand, tend to take on deep renovation approach when there is a need for extensive maintenance measures which imply sizable financial burden. This in practice results in a noticeable rent increase to compensate for the extra costs of renovation. Such a rent increase on the other hand, creates financial burden for the tenants who must allocate a big share of its disposable income (if enough at all) to the accommodation expenses.

The obvious issue regarding renovation as it is practiced today, is its timing and the consequent volume of the renovation project. To get to the bottom of this problem, it is important to know what the most common maintenance strategies are, how they can be devised and how they compare against each other.

4.1. Maintenance strategies

A maintenance plan is devised to keep an asset (a part or a component) at acceptable level of service quality. If we consider (β) to stand for the condition of a respective building element, every element in a building (every deteriorating part or component) follows two deterioration phases expressed by the equations below, (Schröder, 1989):

$$\text{Phase 1:} \quad \beta = 1 - t_i(t/t_i)^{\alpha_1}; \quad \text{Eq. 4-1}$$

$$\text{Phase 2:} \quad \beta = \beta_i(1 - ((t - t_i)/\beta_i)^{\alpha_2}); \quad \text{Eq. 4-2}$$

Where,

β = condition;

β_i = condition at t_i ;

t_i = the time when phase 1 ends and phase 2 starts;

t = time;

α_1, α_2 = exponents determining the form of deterioration behaviour.

If we assume that α_1 is equal to one (based on empirical studies) and α_2 is bigger than one (Meyer, Büchler, Christen, & Waibel, 1995), the figure below, Figure 4-1, illustrates an exemplary model of a condition curve for a building element.

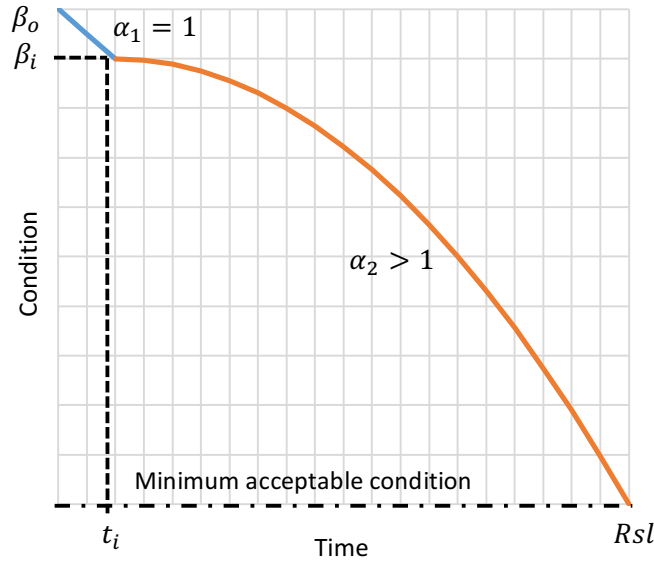


Figure 4-1: An exemplary condition curve for a building element representing a corrective maintenance strategy

In this figure, β_o is the original condition for the building element and Rsl is the reference service life of the respective element. The reference service life in this study is considered to be the service life of a building element at designed conditions with no maintenance measure carried out. Therefore, when a building element is installed, under designed conditions it follows its respective condition curve until it reaches the minimum acceptable condition at its Rsl , which would mark the end of its service life and denotes the replacement time for the respective element. If a maintenance strategy follows this procedure, it is called a corrective maintenance strategy (CMS). In CMS, property owners carry out no maintenance measure unless a failure is reported in case of which the faulty element will be replaced with a new element. Considering the actions required in CMS, the total costs of this strategy correspond to the costs of replacements.

Considering the often-long service life of building elements, having set one level of condition control (service quality) marked as minimum acceptable condition cannot guarantee an optimum performance of the respective elements. Especially for those elements which are composed of different components, having only one level of condition control for all the components can result in partial deficiency of the components which in return will affect the overall performance of the element. Therefore, it is reasonable to have intermediate acceptable condition (condition control levels) for certain elements at time of which maintenance measures are to be carried out in order to improve the service quality, $\delta\beta$, of the respective elements. As it is shown in the figure below, Figure 4-2, the maintenance measure has increased the service quality (condition) of the respective element

by $\delta\beta$, which in return extends its service life by δt years and marks the estimated service life (Esl) as the new service life for the respective element.

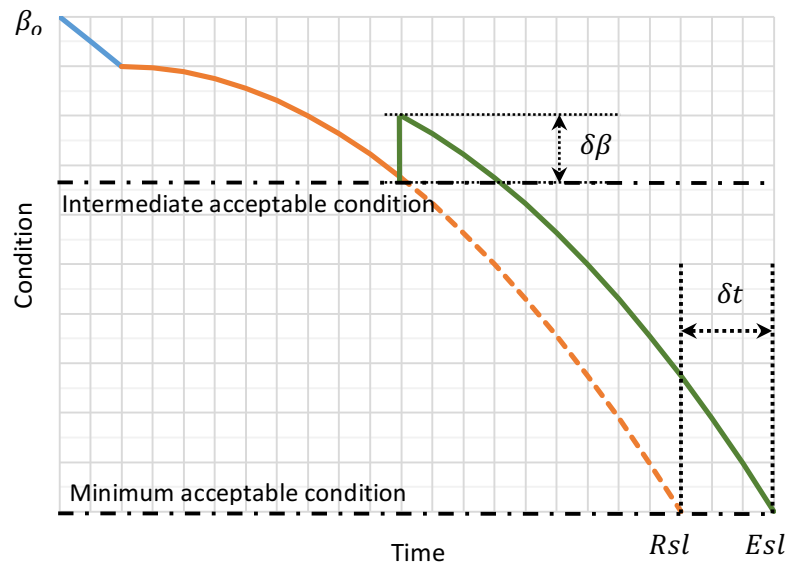


Figure 4-2: An exemplary condition curve for a building element representing a Preventive maintenance strategy

If a maintenance strategy follows this procedure, it is called a preventive maintenance strategy (PMS). In PMS, property owners carry out preventive measures at intermediate condition levels both to improve the performance and extend the service life of the respective elements. Considering the actions required in PMS, the total costs of this strategy beside the costs of replacements, corresponds to the costs of all preventive measures.

4.2. Methodology

In order to devise a maintenance plan, either corrective or preventive, the first requirement is to have a complete registry of all the building elements containing the time of replacement (or the year of construction) and the Rsl for the respective elements. The information regarding Rsl for different building elements can be obtained from the respective manufacturers, statistics, certain publications or local building codes and standards, (ISO 15686-3).

As in CMS the only action required is the replacement of the faulty elements, having access to aforementioned information, we can easily devise a corrective maintenance strategy. Besides, to budget such a maintenance strategy the only required information is the costs of replacement (purchase price) for different building elements.

On the other hand, however, devising a preventive maintenance strategy is quite complicated and demands more information. In the literature, the focus has mainly been on maintenance budgeting rather than on maintenance planning, (Bahr & Lennerts, 2010; Caccavelli, n.d.; Christen, Schroeder, & Wallbaum, 2014; Kumar, Setunge, & Patnaikuni,

2010; Schröder, 1989). The problem with the use of budgeting methods is that they don't offer detailed maintenance plan and the budget estimations are based on optimum historical condition-based replacement and maintenance expenditures.

To devise a preventive maintenance strategy, the first requirement, as mentioned earlier, is to have a complete registry of all the building elements containing the time of replacement (or the year of construction) and the Rsl for the respective elements. Then the Esl or δt need to be estimated. As it is given in the Figure 4-2, the extent of δt or Esl is related to the effect of preventive measures on the condition of the respective element, or $\delta\beta$. Therefore, Esl can be calculated as follows:

$$Esl = Rsl + \delta t = Rsl + t_{pm} - \left(t_i + \beta_i^{\alpha_2} \sqrt{1 - ((\beta_{pm} + \delta\beta)/\beta_i)} \right) \quad \text{Eq. 4-3}$$

where,

- t_{pm} = the time at which a preventive measure has been carried out;
- β_{pm} = the condition of the element at t_{pm} before maintenance;
- δt = the difference between the Esl and the Rsl;
- $\delta\beta$ = the increase in condition of an element after maintenance.

In the equation above, α_2 , can be either estimated using statistical data or can be calculated given the time and the condition of an element are available through inspection. To be able to calculate the Esl, the only remaining variable is then the $\delta\beta$.

The approach in this method to estimate the $\delta\beta$, is based on the relationship between the ratio of the condition improvement to the original condition and the ratio of the preventive measures' costs to the reinstatement value of the respective element. Considering the fact that the condition curve also represent the devaluation of the respective elements, (Schröder, 1989), we can derive the following equation:

$$\delta\beta/\beta_o \sim C_{\delta\beta}/C_{\beta_o} \quad \text{Eq. 4-4}$$

where,

- $C_{\delta\beta}$ = the costs of service quality (condition) improvements;
- C_{β_o} = the reinstatement value for the respective element.

However, for this relationship to be more accurate, the costs of service quality improvements should be broken apart into fixed and effective costs, where the effective costs are the share of the total cost that directly affect the quality improvement and the fixed costs are the costs related to the management and procurement expenditures. Therefore, the

$$\delta\beta = (C_{eff}/C_{\beta_o})\beta_o \quad \text{Eq. 4-5}$$

where,

C_{eff} = the effective share of preventive measure's costs;

C_{fix} = the fixed share of preventive measure's costs.

The relationship in $\delta\beta\beta_0 \sim C_{\delta\beta}/C_{\beta_0}$

Eq. 4-4 between different cost components and the $\delta\beta$, is illustrated in the figure below, Figure 4-3.

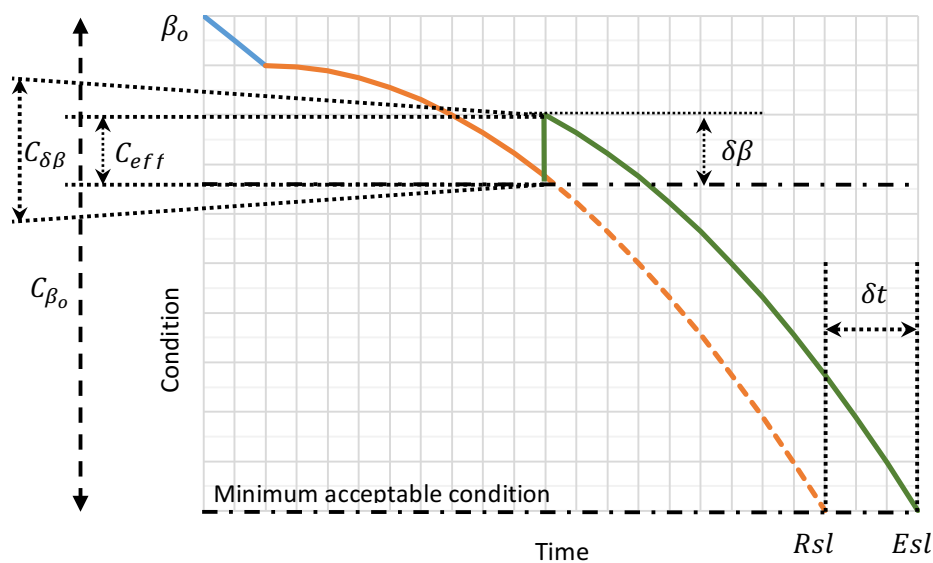


Figure 4-3: The relationship between the cost of a preventive measure and the condition improvement on an exemplary condition curve for a building element

Having estimated the service quality (condition) improvement for an element, $\delta\beta$, using the

$$Esl=Rsl+\delta t=Rsl+t_{pm}-\left(t_i+\beta_i^{\alpha_2}\sqrt{1-\left((\beta_{pm}+\delta\beta)/\beta_i\right)}\right) \quad \text{Eq. 4-3, the}$$

estimated service life (Esl) of the respective element can be calculated. This procedure produces enough information required to devise a simple preventive maintenance strategy. However, for a preventive maintenance strategy to be acceptable the following two requirements must be met:

$$1) \delta\beta + \beta_{pm} < \beta_o; \quad \text{Eq. 4-6}$$

Having fulfilled this requirement means that the service quality (condition) of an element subject to preventive measure cannot increase to more than the original condition of the respective element.

$$2) \sum_{k=1}^m NPV_{PMS} \leq \sum_{k=1}^m NPV_{CMS}; \quad \text{Eq. 4-7}$$

where,

$$NPV_{PMS} = \sum_{j=1}^n \left((C_{\delta\beta_j} * \theta^{t_{pmj}}) / (1+r)^{t_{pmj}} \right) + (C_{\beta_o} * \theta^{t_{Esl}}) / (1+r)^{t_{Esl}};$$

$$NPV_{CMS} = (C_{\beta_o} * \theta^{t_{Rsl}}) / (1+r)^{t_{Rsl}} + (U * \theta^{t_{Esl}}) / (1+r)^{t_{Esl}};$$

$$\theta = (1 + r_s) * (1 + i);$$

$$U = (C_{\beta_o} / t_{Rsl}) * (t_{Esl} - t_{Rsl}).$$

where,

NPV_{PMS} = net present value of the total costs of the preventive maintenance strategy;

NPV_{CMS} = net present value of the total costs of the corrective maintenance strategy;

U = used value of the respective element;

$C_{\delta\beta_j}$ = cost of preventive measure;

C_{β_o} = reinstatement value of the respective element;

r = discount rate;

r_s = service cost growth rate;

i = inflation rate;

j = order of maintenance measures for a single element;

n = total number of preventive measures for a single element;

k = number of element subject to maintenance measures;

m = total number of element;

t = time variable.

The second requirement implies that for a preventive maintenance strategy (PMS) to be economically justifiable, its life cycle costs must be lower than the life cycle costs¹⁸ of the respective corrective maintenance strategy (CMS).

Furthermore, the estimated Esl can be checked against the results from the factor method given by ISO standard (ISO 15686-3), to make sure that the estimations using the method in this study falls within an acceptable range. For example, if the factors for the effects of a preventive measure on the service life of an element are assumed to be 0,9 and 1,1 for two cases with and without preventive measures, respectively, the estimated Esl should fall within the range of, $Rsl (1,22 \pm 0,1)$.

While planning a preventive strategy, a very important variable to decide for, is the time for an intermediate acceptable service quality, or the time at which a preventive measure is to be carried out, t_{pm} . Often this value is decided for based on given instructions or previous experiences. t_{pm} , in this case would be the time after which the same preventive measure carried out (postponed) would result in lower Esl for the respective building element. On the other hand, premature preventive measures are assumed to result in smaller $\delta\beta$ with the same Esl .

Assuming that the C_{fix} of a preventive measure is constant in time (apart from the increase in the costs of services), changes in $\delta\beta$ implies changes in C_{eff} . Therefore, the later a preventive measure is carried out, to achieve the same Esl , the higher the C_{eff} , or the costs of the respective measure. This relationship can be seen in the figure below, Figure 4-4.

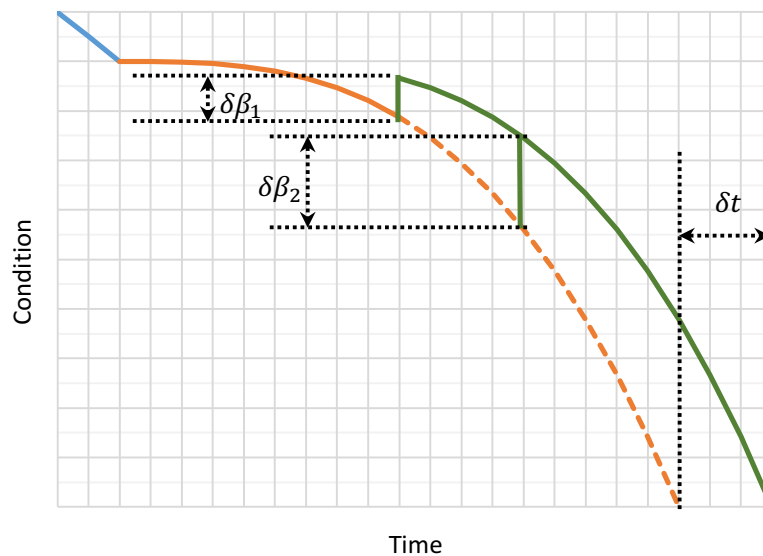


Figure 4-4: the required condition improvements $\delta\beta$, at different times to achieve a certain Esl

¹⁸ The life cycle period for both maintenance plans must be the same

If a desired *Esl* is to be achieved, the maximum allowed expenditure per year for the respective preventive measure can be calculated, Eq. 4-8. These values then should be checked against the costs of the preventive measure at any given year to check if the preventive plan with the given configuration will satisfy the profitability requirements.

$$\delta\beta_{max,t_{pm}} = \beta_o \left(\left((NPV_{PMS} - NPV_{CMS})(1+r)^{t_{pm}} - C_{fix}(1+r_s)^{t_{pm}} \right) / (C_{\beta_o}(1+r_s)^{t_{pm}}) \right) \quad \text{Eq. 4-8}$$

where,

$\delta\beta_{max,t_{pm}}$ = maximum allowed quality improvement at t_{pm} ;

C_{β_o} = reinstatement value of the respective element;

t_{pm} = the time at which a preventive measure has been carried out;

r = discount rate;

r_s = service cost growth rate.

Considering the lower total costs for a combination of different maintenance measures, a more expensive preventive measure carried out at the same time with a number of other preventive measures can result in a more cost-effective maintenance strategy. It is of quite importance to note that not always a combination of different maintenance strategies carried out at the same time will result in a better economy of the project.

Using the method given in this chapter, one can devise either a corrective or preventive maintenance strategy. Both of these strategies have been used in the multi-family building stock in Sweden during the last few decades, with the majority of the housing companies taking the corrective approach, (Boverket, 2003). Considering the financial aspects to be the main reason behind the uneven distribution of the two strategies, it is important to understand the differences between the two strategies in financial terms and investigate whether the presumption that the corrective strategy is a more cost-effective approach is true or not. To do so, an inclusive registry for the most common building elements in the Swedish multi-family building stock was required. Therefore, SABO's registry (SABO, 214) was chosen for the building elements to be used in construction of the two maintenance strategies. These elements and their respective estimated service life are given in the table below, Table 4-1.

Table 4-1: Different building elements and their respective *Esl* (estimated service life) considered in the construction of the two maintenance strategies, SABO's database

Element	Service life (years)	Element	Service life (Years)
Roof (brick tiles)	50	Stairwells	40
Façade (brick)	50	Laundry equipment	30
Windows - wooden 3 m ²	50	Piping - sewage	50
Doors - inside	30	Piping - water	50
Doors - entry	25	District heating centre	30
Floor - wooden	40	Heating distribution system	50

Floor - plastic- bathrooms	25	Circulation pump 1kW	20
Floor - cement	15	Radiators with vents	50
Walls - apartments	15	Exhaust fan unit	30
Walls - bathrooms	15	Exhaust vents	50
Walls - laundry	10	Kitchen exhaust	30
Walls - corridor	15	Electrical system	30
Ceilings - indoor	15	Lighting	25
Ceiling - laundry	15	Garbage management	20
Toilet & bathroom fittings	30	Control and monitoring	15
Kitchen fixtures	40		

SABO's registry include the estimated service life, the required preventive measures, the reinstatement value and the costs of preventive measures for each respective element. The only problem with SABO's registry is that the provided information cannot identify the shape of the condition curve, α , for the given elements. As SABO's registry as a preventive plan, to be able to devise the respective corrective plan, the value of α for each individual element is required. However, for the purpose of comparison, a simplified version of the method (which eliminates the need for α) proposed in this chapter can be used to estimate the respective reference service life for each building element. Since the main advantage of a preventive maintenance strategy is the extended service life of building elements, using this method the Estimated *Rsl* becomes longer than the real *Rsl* for the respective elements given in the SABO's plan, Figure 4-5.

In this simplification, it is assumed that all the building elements subject to deterioration, degrade at a constant rate, α , specific to the respective part. Figure 4-5 illustrates how the service life and the service quality improvement (maintenance) for an element with variable deterioration rate are pictured in as a part with constant deterioration rate. Since only the original condition (β_o) and the estimated *Rsl* are important in the corrective strategy, the level of service quality at the time of maintenance (before improvement) can be disregarded while the effect of maintenance in the condition level ($\delta\beta$) is equal in both variable and constant deterioration cases.

The β is a condition index and is scaled ranging from 0 for the minimum accepted service quality to one (β_o) for the initial (original) service quality. Therefore, the original condition is similar for all the building elements irrespective of their service life, durability or deterioration rates. The condition (service quality) index enables us to compare the deterioration rates and service quality improvements ($\delta\beta$) for different building parts.

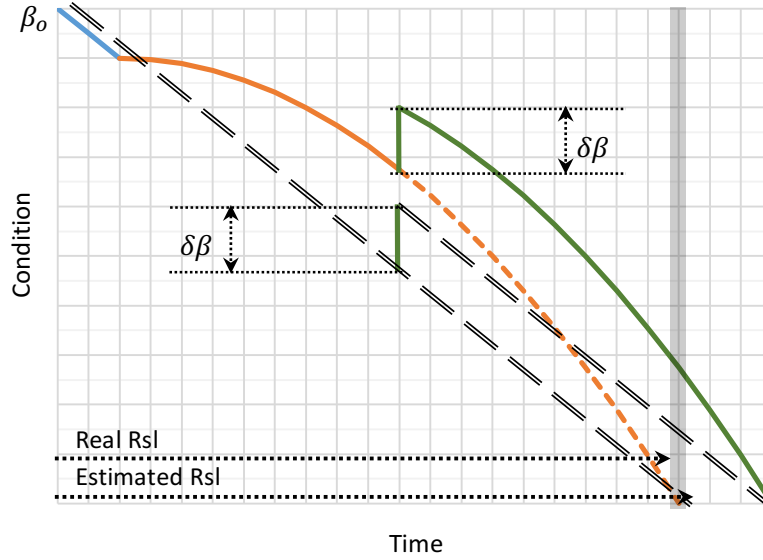


Figure 4-5: Linear condition behavior to estimate the reference service life of different building elements

Since all the building parts start degradation at the same service quality level, the deterioration rate in percentage, can be calculated as follows:

$$\alpha = (1/t_{Rsl}) * 100 \quad \text{Eq. 4-9}$$

where,

$$t_{Rsl} = (\beta_o * t_{Est}) / (\beta_o + \sum \delta\beta_i) \quad \text{Eq. 4-10}$$

Using the equations above, depending on the availability of data, one can estimate the deterioration rate for different building parts. For a part, which is subject to no maintenance measure, knowing either the deterioration rate or the service life, the other parameter can be easily estimated. For the parts subject to one or more maintenance measures, however, the resulting estimation of either the deterioration rate or the service life is highly dependent on the improvements made after each maintenance measure ($\delta\beta_i$).

4.3. Sample buildings

In order to be able to compare and illustrate the differences between the two maintenance strategies, the given simplified method is applied to the building elements given in Table 4-1, on two identical sample buildings each applying one of the two maintenance strategies. Characteristics and specifications of these buildings are chosen so that they represent a typical multi-family building situation in Sweden.

It is assumed that these buildings are owned and managed by a municipal housing company. The total gross area (BTA) in the portfolio is 3960 m², comprising 48 mid-size apartments of 66 m². There are four multi-family buildings and each have three storeys with 4

apartments at each floor (lamellhus). It is further assumed that there are no elevators and no balconies. Each apartment comes with a kitchen, living room, a bedroom and a bathroom. The ventilation system consists of an exhaust fan to facilitate the air change in the apartments, (the most common type from the record years according to (Boverket, 2010)). All the details for the two sample buildings are given below in Table 4-2.

Table 4-2: Details and dimensions of the sample multi-family buildings

Total gross area (BTA)	3960 m ²	Bathroom area	6 m ²
Total living area	3168 m ²	Bedroom area	12 m ²
Total service area	650 m ²	Height of each building	10 m
Green area	400 m ²	Total façade area	2272 m ²
Number of buildings	4	Number of windows on each apartment	7
Number of floors in each building	3	Total area of each window	3 m ²
Number of apartments on each floor	4	Total roof area	1273 m ²
Total area of each apartment	66 m ²		

The total management costs for these buildings are taken from the SABO's 2014 financial report for its housing portfolio, (SABO, 2014) and are given in Table 4-3. These costs are the average values collected from more than 630 000 apartments. The idea is that, SABO's portfolio is big enough to include buildings of different age and values so that the average costs in the yearly report are a good representation for an average multi-family building in the portfolio.

Table 4-3: Building management cost/revenue categories in SABO's yearly financial report

Building management		Cost Kr/m ² , year
Net operation		
	Maintenance	195
	Property tax	19
	Land fees	2
	Operation	
	Janitorial/cleaning	83
	Repairs	61
	Tariff-based	
	Electricity	34
	Water	37
	Garbage collection	22
	Heating	114
	Property administration	59
Loan		115
Central administration		37
Rent		956

For all the cost categories given above, values are used in real terms. The yearly changes follow the growth rates for the respective categories given in the table below, Table 4-4.

Table 4-4: Deficit/Growth factor for different cost categories

Deficit/Growth category	
Rent decrease based on property's age (rent decay)	0%
Electricity/Heating price growth	2%
Inflation (i)	0%
Service cost growth (r_s)	1%

5. Results and discussion

For any housing company the ultimate goal is to be able to utilize its assets' full potential in terms of performance and economy. The performance of every property can be optimized through managing the performance of its individual parts. To be able to properly manage a property, a proper long-term maintenance plan is required which serves for two purposes. The first is to sustain an acceptable performance level for every element during the property's service life and the second is to provide a time frame for future maintenance expenses.

Figure below, Figure 5-1, shows the distribution of costs for the two maintenance strategies as a share of the total cost in percentage over the properties' service life using the values given in appendix 1 for SABO's preventive plan. The costs for the corrective plan have been calculated using the Eq. 4-10. As it is also shown in the figure below, the majority of the maintenance costs (more than 75% of the total costs) for both strategies come forward during the last 20 years of the buildings' service life.

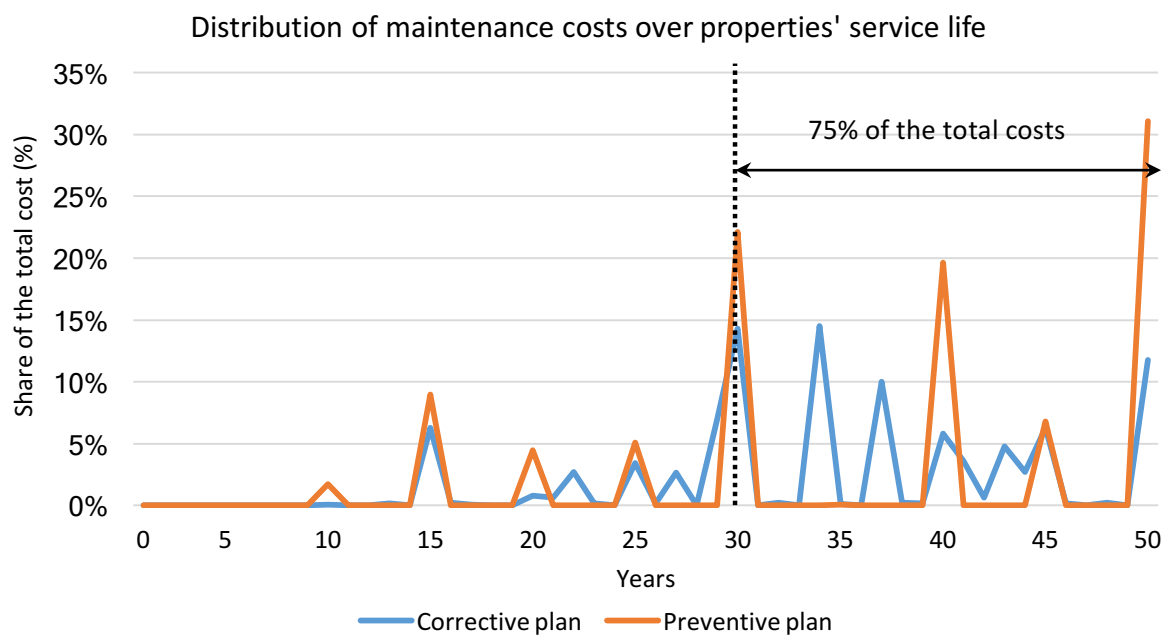


Figure 5-1: A cost distribution over properties' service life for both corrective and preventive maintenance strategies

The resulting maintenance budget distribution given in the figure above is in line with results from (Bahr & Lennerts, 2010) which illustrate the first big maintenance peak that occurs 30 years after construction. The cost distribution given in the figure above, is applied to the sample buildings' total management costs, Table 4-3, and the resulting cost profile for the housing company is shown in Figure 5-2.

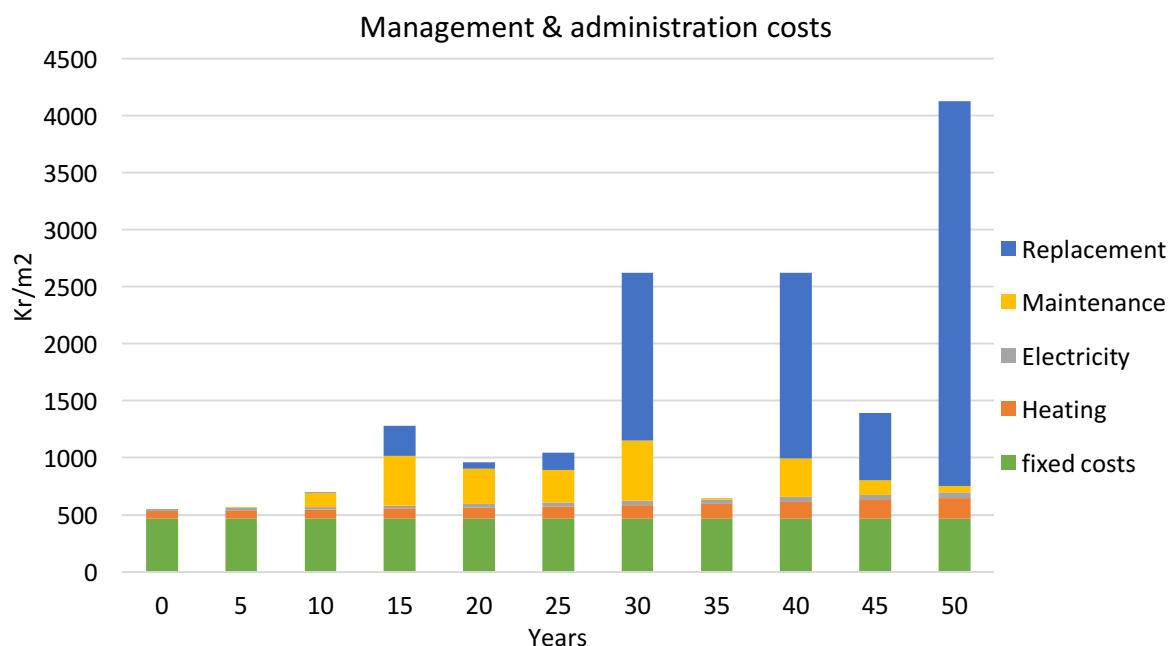


Figure 5-2: Adjusted management & administration costs for the sample multi-family buildings

Given the fact that rents are set so that they cover (beside other expenses) all the maintenance costs, the surplus of net operating income during the early years in theory should be enough to cover the extensive replacement costs of the last 20 years. Nonetheless the current situation of multi-family buildings from the record years point at extensive negligence of maintenance measures. In our understanding, there are two main reasons to why housing companies couldn't manage the high costs of maintenance measures. First, the fact that many of the housing companies owning properties in less attractive areas had to face income deficiencies due to the high rate of vacancy and higher rate of relocation comparing to central areas. The shorter period of settlements for tenants in less attractive areas, not only impose extra transaction costs to the respective housing companies but also can increase the maintenance costs since there are less incentives for self-maintenance amongst short-term tenants. The second reason could have been the fact that, costs of services has increased above the limit at which the extra costs could have been compensated for through rent negotiations, (Bejrums, 1986). These issues beside the overcrowding problems, type of use, operating condition, lack of maintenance plans, etc. created a difficult financial situation for housing companies within which a big share of owners couldn't optimize income and were forced to change maintenance strategies.

Having discussed the current condition of multi-family building stock in terms of technical requirements in previous chapter, one would realize the benefits of a well-maintained property, i.e., better indoor climate, better energy performance, less operation costs, higher demand, etc.

In general, for a housing company, there are few options in terms of building maintenance and renovation, the choice of each have considerable effect on the future of the housing

company's economy, the performance of its properties, its tenants and the governing society. As mentioned in the previous chapter, a housing company (owner) can decide to either keep maintaining its properties; skip regular maintenance but replace parts in case of failure; abandon its properties; keep maintaining its properties and plan for renovation or skip regular maintenance but replace parts in case of failure and plan for renovation.

For a housing company, in order to make an informed decision regarding the maintenance and renovation strategy, the effects of each decision on properties service/economic life and the company's financial performance must be known and well evaluated. The intention in this chapter therefore is to demonstrate these effects for the two maintenance strategies. Furthermore, the effects of energy performance and sustainable social development in such strategies will be discussed.

5.1. Possible strategies

Considering the current condition of multi-family building stock in Sweden, discussions are around the need for renovation and the necessity of implementing energy efficiency measures. The question here is, why renovation is important and to whom?

But before getting to the importance of renovation one should understand the importance of the less pronounced maintenance plan. After all, between 50-80% of the total renovation costs in renovation projects must be attributed to maintenance measures, (Boverket, 2003). This understanding can possibly shed light on some of the aspects of financial difficulties in renovation projects and potentially offer help in cost management prior to planned renovation activities. Therefore, the aim in the following section is to study the financial performance of the sample housing company under two maintenance strategies (preventive and corrective) and illustrate the effects of each strategy on the future (economic/service life) of its properties.

In order to study the effects of these strategies on the economy of the housing company as well as on the future of the properties, the service life of all building elements for both strategies are estimated using the method given in previous chapter. The deterioration behaviour of these elements and the resulting service lives for the first 50 years in both strategies are shown in figures below, (Figure 5-3, Figure 5-4). Regardless of the type of chosen strategy, it is important to remember that when a decision has been made for cost reductions through reduced maintenance activities, income optimization can only happen when reduced expenditures are of quality improving maintenance type; not the replacement costs. Neglecting replacements alters the functionality of a property thus is not considered in this study.

As it is shown in these figures, the quality improvements are only visible in preventive plan, Figure 5-3, while the replacement time (service life) for the majority of the building elements are pulled forward in corrective maintenance strategy, Figure 5-4. The deterioration behaviour for a single part is highlighted in both figures, illustrating how preventive maintenance extends the service life for the respective part.

The given behaviour of different deteriorating elements in these figures in both maintenance strategies imply incomparable economic outcome for the managing housing company. The chaotic nature of corrective maintenance strategy not only creates a difficult situation for cost management but increases the possibility for unexpected repair, rapid decay and failure costs, (Manganelli, 2013).

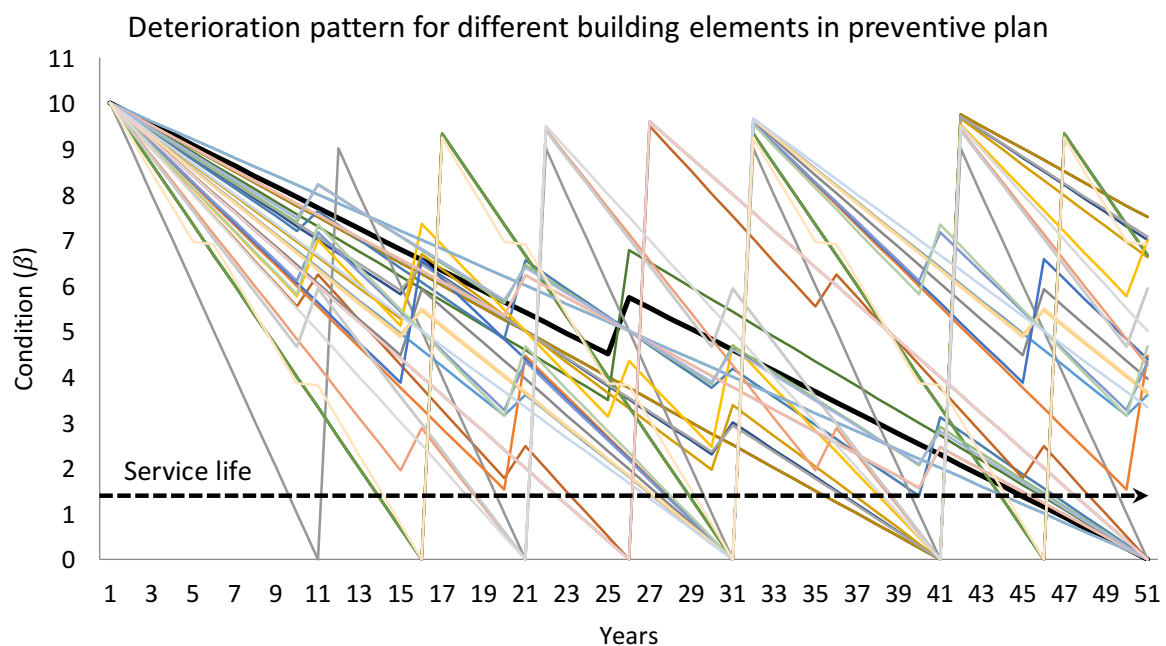


Figure 5-3: the service life and changes in condition for different building elements in preventive maintenance plan

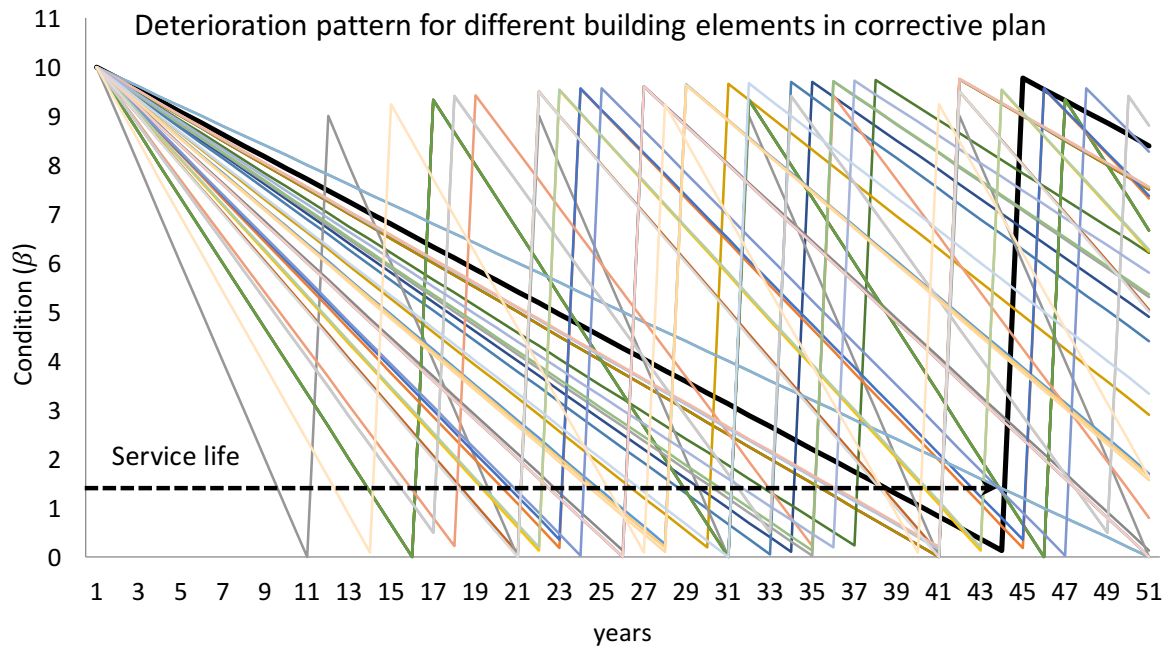


Figure 5-4: the service life and changes in condition for different building elements in corrective maintenance plan

5.1.1. To maintain (both corrective and preventive)

If the decision has been made for the given properties to be maintained over their entire service life, figure below Figure 5-5 shows how different distribution of maintenance activities, in both the corrective and the preventive strategies, can affect the economy of the managing housing company. The calculated numbers in this figure are the present value of the accumulated yearly cash flows. As it can be seen, during the first 25 years there is a slight economic advantage to the corrective strategy. The higher net operating income during this period comes from savings made through negligence of preventive maintenance measures. However, from this point forward, the NPV of the preventive plan sets apart from the NPV of the corrective plan. This economic gain gradually grows until the properties reach 50 years of age at which point the net present value difference of the earnings between the two strategies exceeds 600 Kr/m² (1,9 million Kr). This difference, given the circumstances, defines the limit for the profitability of the initial capital expenditure. In case the given strategies remain in force, this gap continues to grow by the end of the next 50 years. Although the values given in this figure for the second 50 years show the difference between the two strategies, due to increasing insensitivity of the NPV (net present value) method in such a long period, it fails to demonstrate the magnitude of the difference.

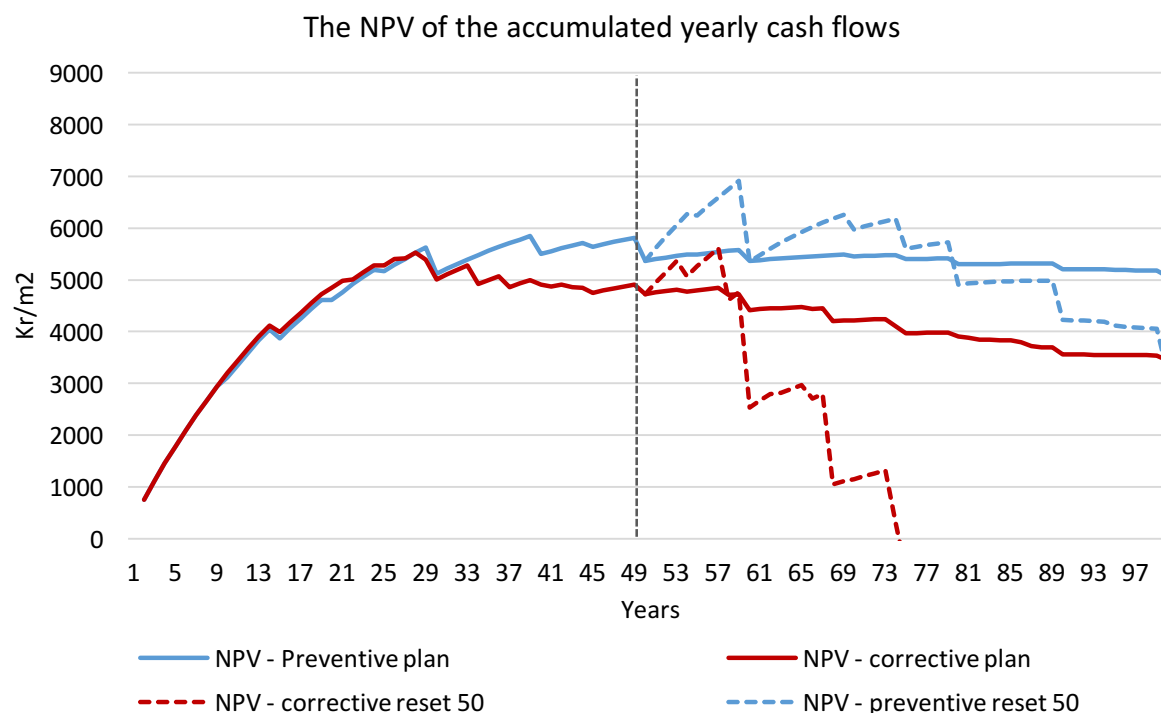


Figure 5-5: The net present value of the accumulated yearly cash flows (excluding the initial capital costs) for the sample buildings in different maintenance strategies

To fix this problem, the NPV for the two strategies for the second 50 years has been calculated separately assuming the year 50 to be the starting point for the calculations. The results then are shown in the figure above using blue and red dashed lines for the preventive and corrective strategies, respectively. As the figure displays, there is a big difference¹⁹ in the cost/revenue between the two strategies during the second 50 years which indicates the much bigger replacement costs associated with the corrective strategy.

It is important to note that, in calculation of the net present value of the future cash flows for the two given maintenance strategies the rents are considered to be the same in both cases. However, in practice the physical deterioration of building structure is not curable through maintenance resulting in an income decay. The physical deterioration marks the difference between an aged property and a new construction. Such consideration would increase the already large income difference between the two scenarios.

Besides, under normal housing condition, where there is no housing shortage, a similar rent for both a well-maintained and an un-maintained property would impose higher risk of vacancy on the un-maintained property which would result in even shakier economic performance. Whereas, in Swedish housing market due to the existing housing shortage

¹⁹ the new figures are produced only to show the magnitude of the difference between the two strategies therefore values given in the figure should not be used individually.

(especially in bigger cities), an unmaintained property could easily be rented out at similar costs to an identical well-maintained property.

While Figure 5-5 shows the effects of different maintenance strategies on the cash flow of the managing housing company, it somehow misrepresents the effects of such strategies on the economic life of the respective properties. As shown in previous figures, (Figure 5-3, Figure 5-4), the service life of building parts can be extended through regular maintenance. This could be referred to as, the service life of the property (as a whole) can be extended through regular maintenance, ((Manganelli, 2013)). Clearly, the economic life of a property cannot be longer than its service life. However, unlike the latter, it can be considerably reduced by the variation of the market it operates at, i.e., functional obsolescence, changes in the land price, socio-economic problems, and so on.

Nevertheless, in this section the only relevant variation of the housing market which together with the choice of maintenance plan can affect the economic life of the respective properties, is the land value. If the value of a given property is the sum of the values of the land and the building itself, these two values are estimated as follows:

The starting value of the land for the sample properties is considered to be 200 Kr/m² and is chosen only for demonstration purposes. Moreover, its value is assumed to be linearly increasing at 15% growth rate. (The average growth rate for three bigger cities and the smaller cities, during the last 20 years, have been 18% and 25%, respectively, (SCB, 2014)).

On the other hand, the term market value used here is a consideration of property's current financial performance at any given time and its potential benefits in the future. This valuation can be formulated using the DCF (discounted cash flow) method which is thought to be appropriate for income producing properties²⁰.

$$\text{Market value} = \sum_{t=1}^n (C_t / (1 + r)^t) + S_{n+1} / (1 + r)^{n+1} \quad \text{Eq. 5-1}$$

where,

$$S_n = C_{n+1} / Y_n$$

²⁰ It is important to remember that the following results are produced using available data and are only for demonstration purposes. Changes in buildings' cost/revenue profile can strongly influence the results. The aim of this study is to illustrate the differences between the two maintenance strategies in monetary terms. Changes in the cost/revenue profile can strongly influence the results individually but not comparatively.

where,

- C_t = net operating income (NOI) during year t ;
- S_n = salvage value by the end of the year n ;
- r = the discount rate, 4%;
- t = time variable;
- n = analysis period, 8 years;
- Y_n = Yield by the end of the year n , 4%.

Using the DCF method for property valuation, the market value reflects not only the financial performance of the property (its net operating income) but also takes into account forthcoming major costs (maintenance expenditures). When the calculated market value for either of the maintenance strategies reaches zero, the respective year marks the end of the property's economic life. In order for the results to be comparable, it is assumed that the market conditions are same for both scenarios. Figure below, Figure 5-6, displays changes in the market value of the sample properties under different maintenance strategies and the extent of their respective economic life. As it can be seen, the figures exhibit steep fluctuations in the market value. Since the maintenance expenditures are what sets the two values apart, the sharp decrease in the market value signals upcoming expensive maintenance measures during the next 8 years. Consequently, the sharp increase in the market value happens after the respective maintenance has been carried out. In the case of the corrective plan, even though the market value rises during the properties' late 40s, the massive volume of required maintenance measures right after 50 years shrinks its market value and increases the gap between the two strategies. This reduction in value continues down to zero within just few years and sets 55 years as the economic life of the respective properties. As for the preventive plan, the moderately distributed maintenance expenditures extend the properties economic life by 18 years comparing to the corrective plan and sets 73 years as the economic life of the respective properties.

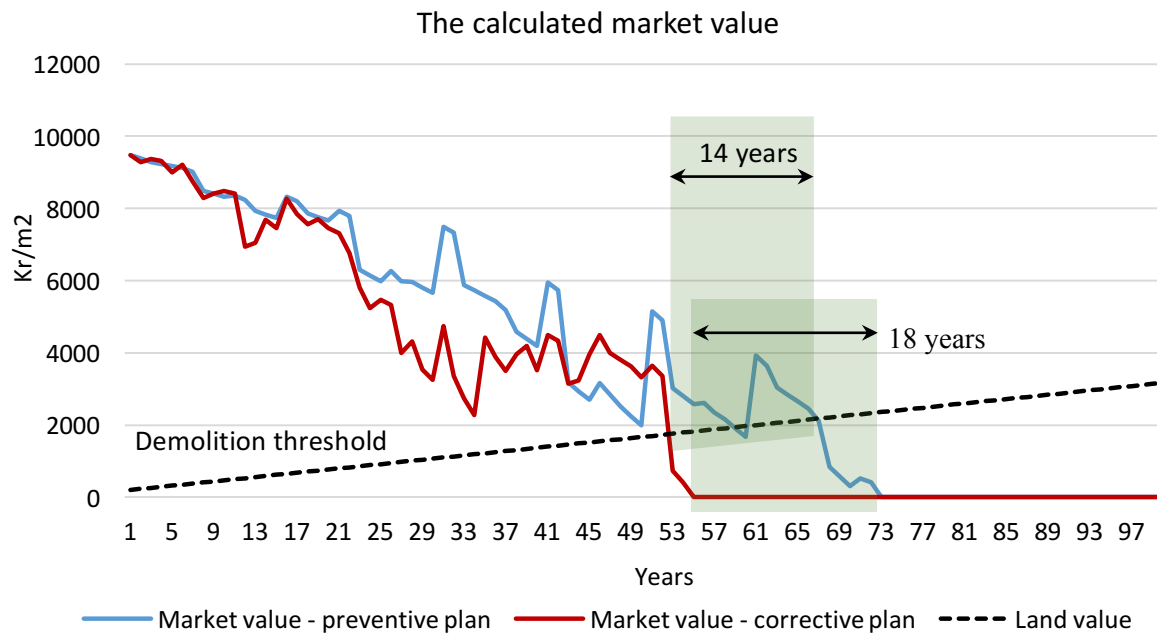


Figure 5-6: The market value of the sample properties under different maintenance strategies as well as the respective land price

However as discussed earlier, the extent of the economic life is also influenced by external variations in the housing market where the respective properties operate at. Here in this figure, the land value and its growth is given as one of the variants of the housing market.

Since the value of a property is the sum of values of the land and the building, the land value marks the lowest value of the respective property, after which the property's operation does not make financial sense. In another word, this limit marks the end of the property's economic life. In the figure above, Figure 5-6, when the market value line and the land value line meet, the property needs to either be renovated, demolished or repurposed. That's why the land value line in this figure is also called the demolition threshold (the demolition cost is assumed to be subtracted). Considering the effect of the land value, the useful economic life for the corrective and the preventive plans become 53 and 67 years, respectively, marking a 14-years gap between the two strategies. The extended economic life of properties due to application of preventive plan denotes how fundamental the choice of maintenance strategy is in the efficiency of the financial resources used.

Here there are some important considerations to bear in mind while processing the figure above. First is the fact that, in case maintenance costs are distributed more evenly over properties' service life, the market values will not fluctuate as much but will display a concave shape pattern as given by empirical studies, (Fisher, Smith, & Stern, 2005). These studies mainly use the sales comparison method for property market valuation, according to which the historical transaction records are used to estimate a similarly conditioned property. Besides, in the calculation of the market values given in the figure above assumptions were made only to illustrate the effects of different maintenance strategies, i.e.,

same yield value for both scenarios, no rent decay, constant repair costs, etc. taking these factors in to account, the economic life of the properties using corrective plan will be considerably reduced. Moreover, in property market valuation, usually a combination of different methods is used for better estimation of the property' real value.

In addition to what have been discussed above, in market valuation by potential investors, there are number of factors involved which make up for the high risk associated with investment in unmaintained properties. For example, lack of maintenance, alters functionality of the property which not only increases the replacement costs (in unit of time) but also can result in number of issues, i.e., unacceptable indoor climate, safety issues, lower social status for the tenants and so on. All these problems negatively affect the attractiveness of the property in the eyes of both the investor and the tenant. In the latter case, it can result in relocation of tenants and consequently higher vacancy rate of the property.

Regulatory issues

So far in this chapter, we discussed how a proper maintenance plan can extend the economic life of its respective property. We've also talked about the effects of external market variants. Besides, we know how the composition of tenants and the socio-economic issues can negatively influence the condition of properties. However, in order to have a better picture of the current situation, we need to touch upon some regulatory issues in the Swedish housing market.

For any housing company (owner), in order to sustain a balanced economic performance while maintaining its property, it is important to be able to make reservations for future maintenance costs. As mentioned earlier in previous chapter, since 90s, municipal housing companies have been limited in this regard, (Boverket, 2003), meaning that in such organizations, un-taxed income couldn't be used for upcoming maintenance expenditures. Considering the low profit margin for such companies, this limitation would impose unprecedented problems to housing owners.

Obviously, for a non-profitable (until recently) organization, it's not easy to produce capital. One option for bigger municipal housing companies could be to sell parts of its stock and stack enough capital to cover the maintenance needs of the other part. This option nevertheless requires detailed evaluation of the opportunity cost in order to determine if the revenue from this transaction, is enough to cover both the potential revenue from the sold stock and the required investment cost for the maintenance.

Another regulatory issue which could have facilitated property management is the limitation in the application of different depreciation methods. In the Swedish tax system, only the straight-line depreciation method is allowed for writing off investments or capital expenditures. While the method offers simplicity in calculations, it does not accurately reflect the deterioration of the respective asset, (Berk & Demarzo, 2014). It is argued that

progressive methods best represent buildings' deterioration and use in which the amount of depreciation increases by the age of the asset, (Nordlund, 2010). However, such methods do not offer any advantage to municipal housing companies in terms of tax deductions and income optimizations. In order to cover for maintenance costs during the latter years of buildings' service life, it is crucial to be able to save more money during the early years. It is therefore the author's understanding that accelerated depreciation methods can help the situation with municipal housing companies. Using such methods will enable municipal housing companies to channel more money toward safe investments, i.e. governmental bonds, which in return can pay back for future maintenance needs. Besides, if a share of capital investments comes from bank loans, the savings made during early years could be used to make additional payments.

This situation is completely different for housing cooperatives, where companies are allowed to make reservations for future maintenance costs. Such reservations while being useful, demand altered depreciation use to optimize income. Besides, the method used for depreciation can strongly affect the equality for future owners. In such companies the use of progressive depreciation would mean better opportunities to stabilize fees during early years while making reservations for future maintenance costs. However, since progressive depreciation pushes taxes forward, it imposes financial difficulties to prospective tenants during latter years. This could mean increased fees for new owners who did not benefit from lower costs during early years. At the same time these higher costs could be counteracting the effect of inflation as depreciation is inflation insensitive. However, in case of ownership transfer, the previous owner does not get to benefit from reservations on his costs during early years. In such situations, the decision should be made to protect the rights of both parties in terms of depreciation and maintenance costs.

The mitigation timeframe

The current situation with rental multi-family buildings in Sweden presents a challenge very close to what have already been discussed here. The situation is complex in nature and very specific to the local market and building condition. Buildings have reached/passed their 50s and are in urgent need for extensive maintenance measures. Therefore, regardless of the complications involved, a decision has to be made before buildings reach the end of their economic life cycle.

The timeframe for this decision, among other things, depends on variations of the market, i.e., the land value. The land value shows different behaviour in different market situations. For example, in more central (attractive) areas, the land value grows at higher pace than in suburban areas (25% to 18% on average, SCB). This difference means shorter economic life span for properties in central locations comparing to less attractive areas. To illustrate this effect, Figure 5-6 is reproduced, this time with a land value figures representing both a central and a suburban area, Figure 5-7.

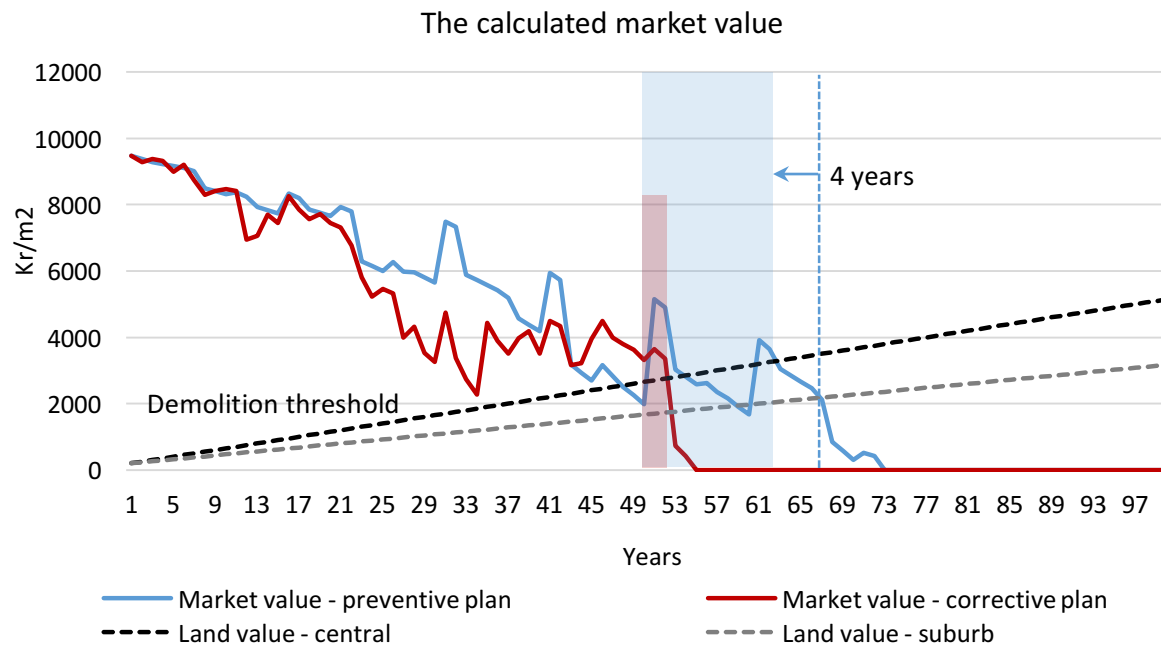


Figure 5-7: The market value of the sample properties under different maintenance strategies as well as the respective land price (central location)

In Figure 5-7, there are two very important periods for the managing housing company the extent of which are displayed by red and blue coloured areas for both corrective and preventive maintenance plans, respectively. These periods in this study are called the mitigation timeframes. The extent of the mitigation timeframe defines time boundaries for an action plan to extend the economic life of any given property. The beginning of this period for the sample buildings are marked at 50 years of age when the costly measures reach the end of their service life and need to be replaced. The end of this period, on the other hand, is marked at the end of the properties' economic life. As it can be seen, the extent of the mitigation timeframe is influenced by both the choice of maintenance plan and the external market variations (land value in this case), Figure 5-7. Comparing these two areas, one would notice the effect of location (land value in different locations) on the extent of the mitigation timeframe specially in buildings with preventive maintenance strategy where moving from suburb to central area shortens the extent of the mitigation timeframe by 4 years. This difference for buildings with corrective maintenance strategy is insignificant in this case.

The mitigation timeframes defer in size from building to building, market to market and company to company. It depends on the current condition of a property, forthcoming maintenance needs, its economy, housing market, internal interests, and so on. Nonetheless, as mentioned earlier, a decision must be taken within this timeframe to prolong the economic life of respective properties. This decision is of complex nature and needs multidisciplinary skills and expertise.

The timeframe, for buildings in urgent need of extensive maintenance measures, is quite short in both central and suburban markets which limits options for decision makers. However, considering the longer timeframe for buildings with preventive plan (in better condition), adopting to preventive strategy could be a short-term option that helps managing housing companies prioritize their action plan. It should be noted that such adaptation does not necessarily mean the same extend economic life. The effects of preventive plan depend solely on the condition of the respective property and the type of forthcoming maintenance needs.

As we saw earlier, through maintenance and replacements, the service life of building parts can be prolonged and reset. Therefore, if there were no limitations, the building would continue to operate until its physical structure could no longer withstand its working environment. This could mean a service life of around 200 years. However, as discussed later, the economic constraints bounded by the Swedish rent control system, define the economic life of a rental property which in principle is much shorter if the building is to be only maintained and renewed.

Knowing that in the Swedish rental market, the only way to boost the economic performance of rental properties (thus prolonging the economic life) is to improve the utility value of the respective properties, regardless of the location, renovation becomes the only option for the managing housing companies if properties are not to be demolished or repurposed.

5.1.2. Renovation (modernization)

Although the economic constraints denote the necessity of modernization (renovation), there are other factors which under normal housing condition, force housing companies into renovation practice. Technical and functional obsolescence are for example two factors that can affect the nature of decision made when a property is to be maintained/renovated.

When properties are built, they often adhere to the standards of the given local market, i.e., floor plan, design, kitchen fixtures, etc. In a well-functioning society, preferences change and along with technological development form new desires and demands. While the dynamic changes in the market, these properties fail to comply with recognized utility. In other words, they become obsolete as their features are not practical or desirable anymore. This phenomenon is called functional obsolescence. On the other hand, the same can happen to technical installations and materials used in construction of properties which in that case it is called the technical obsolescence.

Since changes in the accepted quality (utility value) is influenced by what determines also the land value, the rate of increase in accepted quality is the same as the rate of increase in the land value (the threshold demolition line), (Manganelli, 2013). In the Swedish rental

market, this accepted quality is the instrument used during rent negotiations for new rent levels between housing companies and the local tenant association.

In general, when a property reaches its service life, a decision has to be made. we have already discussed what happens if the decision is to replace the parts and maintain the property. The decision to carry out extensive maintenance measures follow the common economic principle, the profitability. Since the purpose of maintenance is to sustain/retain the original standard, it does not qualify for rent increase thus produce no extra income. Knowing that increase in utility value can result in increased rental income, when a property reaches its service life, instead of maintenance (replacement of building parts) renovation becomes a common practice. Modernization (renovation) not only results in higher rental income, but contributes in higher market valuation as well as longer economic life of the property. However, modernization and its benefits are strongly affected by the market conditions and the value drivers.

To study the effects of renovation on the economic life and the financial performance of the sample properties, number of assumption have to be made which makes the produced results only comparable between the two maintenance strategies and only applicable to the sample properties in this study. Nonetheless, assumptions in this study are made using available data on previous renovation projects and are considered carefully to not misrepresent the reality. Renovation in general is complex and its costs and revenues differ extensively from case to case. For that reason, it has been decided that renovation in this study is a total renovation (excluding energy efficiency measures) and is detailed according to SABO's renovation guideline, (SABO, 2013a). the package includes a complete inner apartment overhaul in addition to replacement of water and sewage piping. The cost of renovation is then calculated at 2696 Kr/m² excluding the maintenance measures, (total renovation cost per square meter living area, (SABO, 2013b)), which is line with the average cost in previous renovation projects, (Stockholms stad, 2015). The corresponding rent increase is assumed to be 25% and is below the average of 33% in previous renovation projects, (Mangold, Österbring, Wallbaum, Thuvander, & Femenias, 2016). Finally, the repair and maintenance costs are assumed to be increasing by 1% yearly.

Since the costs spent on renovation are considered as investment, profitability is always a concern. Profitability of an investment depends strongly on the assumptions made for a number of variables, i.e. discount rate, energy price growth factor and the period of investment. Besides, a complete knowledge of the costs involved in the investment is a necessity. Considering all the facts, it is easy to realize that profitability is not absolute and individuals' interests and incentives can easily determine its outcome.

Figure below, Figure 5-8, illustrates changes in the cash flow of the renovation scenario applied to the sample buildings in this study using two maintenance strategies. The values calculated for the second 50 years have year 50 as the reference year, which is the

renovation profitability period. The two business as usual scenarios from Figure 5-5 are also given as reference values for better evaluation of renovation financial performance. It should be mentioned that the existing maintenance strategy is applied to the post renovation scenario in each respective case meaning that for example, buildings with corrective plan will continue to use the corrective strategy. The results given in the figure below, display a huge difference between the two strategies. In the corrective plan, although the post-renovation cash flow has been improved (due to the increase in rental income), the investment in modernization under given conditions fails to pay off with a big margin (the red arrow). Whereas, in the preventive plan, investment in modernization (renovation) is considered profitable as the NPV remains positive (above the blue area) by the end of the investment period. Comparison between the two scenarios denote the effects of maintenance expenditures during the second 50 years of the buildings' service life knowing that the renovation strategies and the associated costs are the same for the two scenarios. The difference in the maintenance expenditures between the two plans during the second 50 years reveals that replacement cycle costs are more expensive than the preventive maintenance costs.

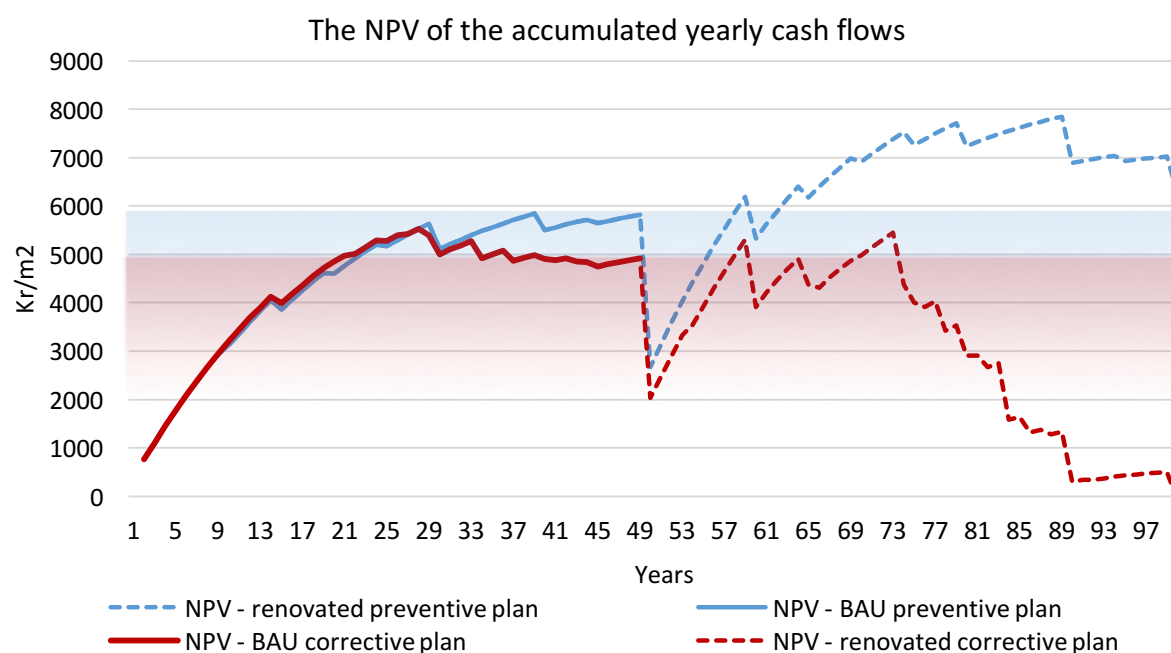


Figure 5-8: the net present value of the accumulated yearly cash flows (years 51-100) for the sample buildings in different maintenance strategies in both BAU and renovation scenarios

Because of the continuous increase in accepted utility value which pushes properties toward functional obsolescence and the land value which shortens the extent of properties' economic life, properties must be modernized. On the other hand, the rent increase is an important economic key driver for renovation (modernization). While the accepted utility value (service quality) in the respective location sets the limit to how far modernization can go, the tenants' (existing and/or prospective) willingness to pay indirectly controls how much the rent can be increased for the respective level of modernization. Considering the smaller gap between the controlled rents and the free market rents in less attractive

locations, beside the lower willingness to pay in such locations, the amount equal to which the rents can be increased after renovation (modernization) projects is very limited which makes it really difficult for the housing companies to economically justify such projects.

Besides the profitability issues mentioned above, to illustrate the effects of renovation on buildings' economic life, equation 4.5 is used to calculate changes in the market value of the respective properties after renovation, Figure 5-9. As it is shown in the figure below, modernization, under given conditions, not only has improved the buildings' economic life (18 and 16 years for buildings with corrective and preventive maintenance strategies, respectively), but has increased the estimated market value of the buildings by 7000 Kr/m² on average. Considering the effect of the net operating income in the estimation of the market value, if profitability was achieved, obviously, the buildings' economic life would extend beyond the current values given in the figure below, (71 and 83 years for buildings with corrective and preventive maintenance strategies, respectively)

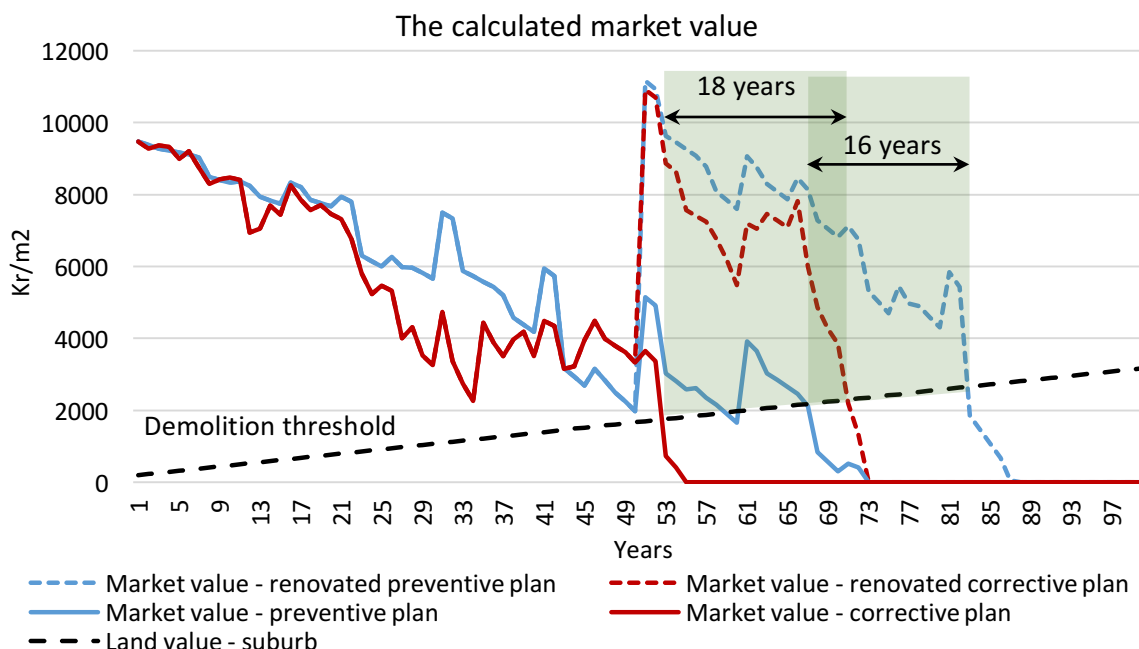


Figure 5-9: The market value of the sample properties with and without renovation under different maintenance strategies as well as the respective land price

So far it has been shown how the application of a preventive maintenance plan is beneficial to both the property itself and the economy of the housing company. What has not been discussed though is, an advantage given by the fundamentals of the preventive maintenance strategy, its potential to be optimized. Optimizing a maintenance plan can be beneficial both in terms of the economy of the plan (overall economy) and the economy of modernization (renovation).

All the results given in previous discussions, have been calculated based on SABO's maintenance plan. Since, renovation is not considered in the making of this maintenance plan, its application when planning for modernization (renovation) becomes complicated.

In SABO's plan, quality improving maintenance measures for each building part are proposed so that the respective part reaches its potential service life. In case of renovation, such an approach can impose unnecessary over-maintenance costs to the owner. For example, when a property is planned to be renovated at time " t ", replacement costs at certain period of time around " t " (especially those with high share of fixed costs) should be avoided. Therefore, for these parts, the maintenance plan should be adjusted so that the replacement time for the respective parts shift toward " t ". Looking back at Figure 5-3, one would realize the potential for adjustments in the preventive maintenance plan applied to the sample buildings in this study, to avoid over-maintenance and reduce extra costs with regard to renovation.

Floors, indoor walls, inner ceilings, toilet fittings and kitchen fixtures, were those measures the service life of which cycled around 50 years thus were considered for adjustment of the maintenance plan. Reducing the unnecessary maintenance measures regarding upcoming renovation at year 50, the NPV for the revised preventive plan were calculated and the results are given in the figure below, Figure 5-10.

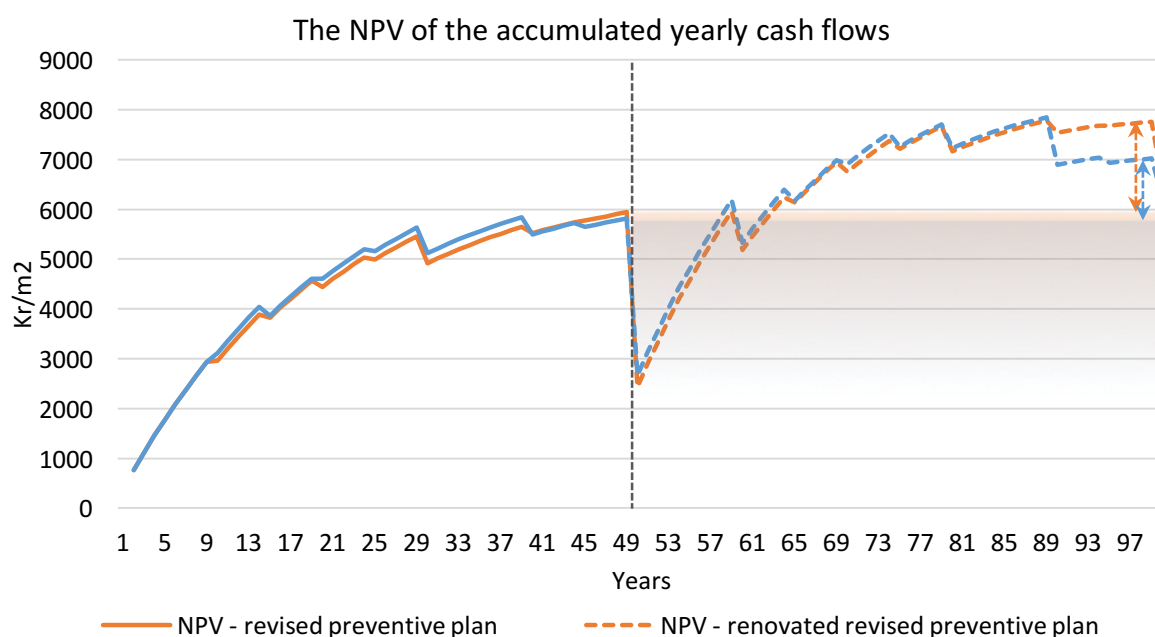


Figure 5-10: the net present value of the accumulated yearly cash flows for the sample buildings in preventive maintenance strategies with and without adjustments in both BAU and renovation scenarios

As it is shown in the figure, there are insignificant differences (in monetary terms) between the two versions of the preventive strategy during the first 50 years although with a slight advantage to the revised plan at year 50 before the submission of the renovation plan. Calculating the values for the second 50 years (renovation profitability period) with the year 50 as the reference year, the differences between the two versions become evident. In Figure 5-10, the two blue and orange areas represent the profitability threshold for the preventive and the revised preventive plans, respectively. Despite having lower threshold,

the revised preventive plan proves to be almost twice as efficient as the original preventive plan (size of the two arrows).

Considering the different distribution of maintenance costs in the adjusted corrective maintenance plan, besides its effect of the profitability of the renovation, it is important to study how such adjustments can affect the economic life of the respective properties. Therefore, the market value of the sample buildings and the resulting economic life for both the original and the revised preventive maintenance plans are calculated and displayed in the figure below, Figure 5-11.

It is not surprising that the difference in the market value between the two maintenance plans is highest during 30-50 years and 80-90 years of age of the sample properties since the majority of adjustments have been made to the parts with their service life cycle around these periods. As it is shown, the adjusted maintenance plan not only improves the market value of the respective properties close to the end of each service life cycle, but extends the economic life by 7 years and marks 90 years as the end of the properties' economic life.

The given information exemplifies how essential the consideration of renovation is in the making of the maintenance strategy. Such considerations are specific to individual properties and are often affected by both internal and external variants, i.e., the land price, economy, demand, willingness to pay and so on.

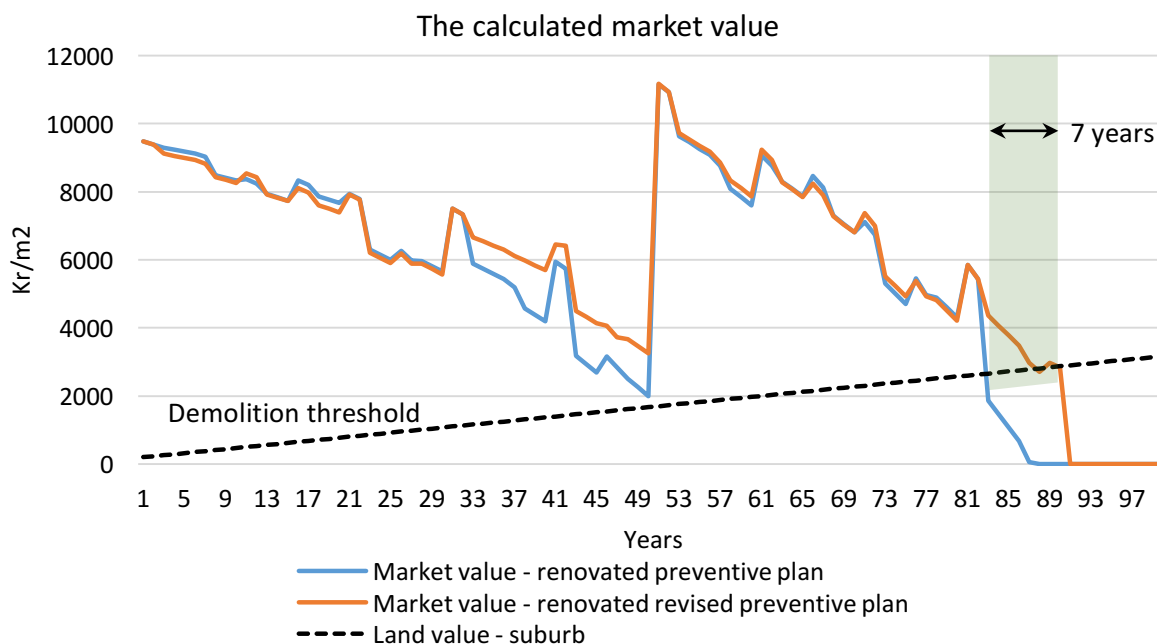


Figure 5-11: The market value of the sample properties for both original and revised preventive maintenance strategies as well as the respective land price

One other factor which is relevant regarding maintenance optimization, is the uncertainty in determining the exact renovation time. This time is usually defined by the time the costly

measures in a property are to be replaced, (the end of service life for mother components). This time is strongly affected by the wear and tear of the property which itself is dependent on the level of maintenance. Therefore, for a well-maintained property, the chances that the planned time for renovation is unchanged, are higher than in less maintained/abandoned properties. In such properties, the rate of failure because of proper maintenance is low. While, in a property where the maintenance is either reduced or neglected, the renovation time is less certain and can vary sometime to large extent. In either of these cases, if before the planned renovation time, one or more of the costly parts fail, it is not economically acceptable to both replace these parts and yet renovate after a short while. This can impose extra costs on the managing housing company either in terms of extra replacement costs or higher replacement costs per unit of time. Consideration of such risks is important when a decision has to be made regarding the application of maintenance strategy.

Usually when an expensive part of a property has reached failure, the opportunity is seized to combine other measures (preferably those at the verge of their life-cycle) in order to lower the total costs of maintenance/renovation (opportunistic maintenance). Since the use of opportunistic maintenance is a common practice, the following example is given to clarify the importance of life cycle cost analysis while evaluating different maintenance strategies.

In this example, it is assumed that windows and façade are the two measures replacement of which is supposed to happen at the same time in case one reaches failure. It is further assumed that windows and façade have the *Rsl* of 32 and 41 years, respectively. The following figures show the deterioration behaviour of the two measures for both corrective and preventive maintenance strategies, Figure 5-12, Figure 5-13.

Given that the windows reach their minimum condition level at year 32 and need to be replaced, it can be rational to replace the damaged façade earlier at the same time as the windows instead of at year 41. Combining these two measures would result in reduced fix costs that can be justify the premature replacement of the façade.

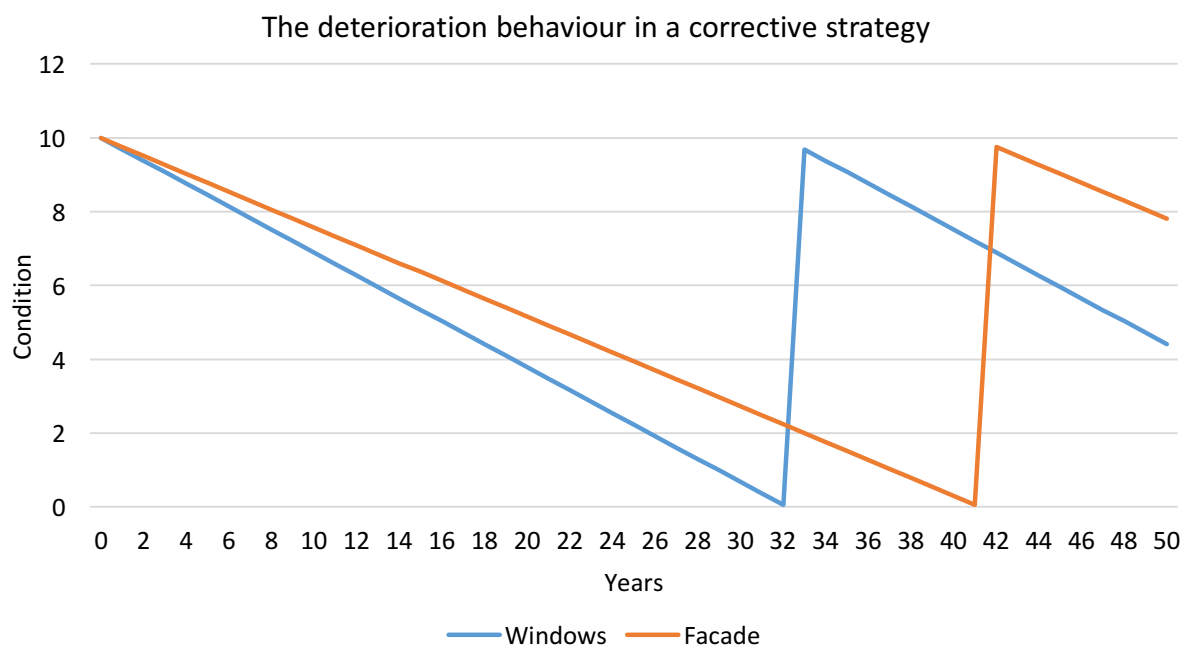


Figure 5-12: The service life and deterioration behavior for two building elements in corrective maintenance strategy

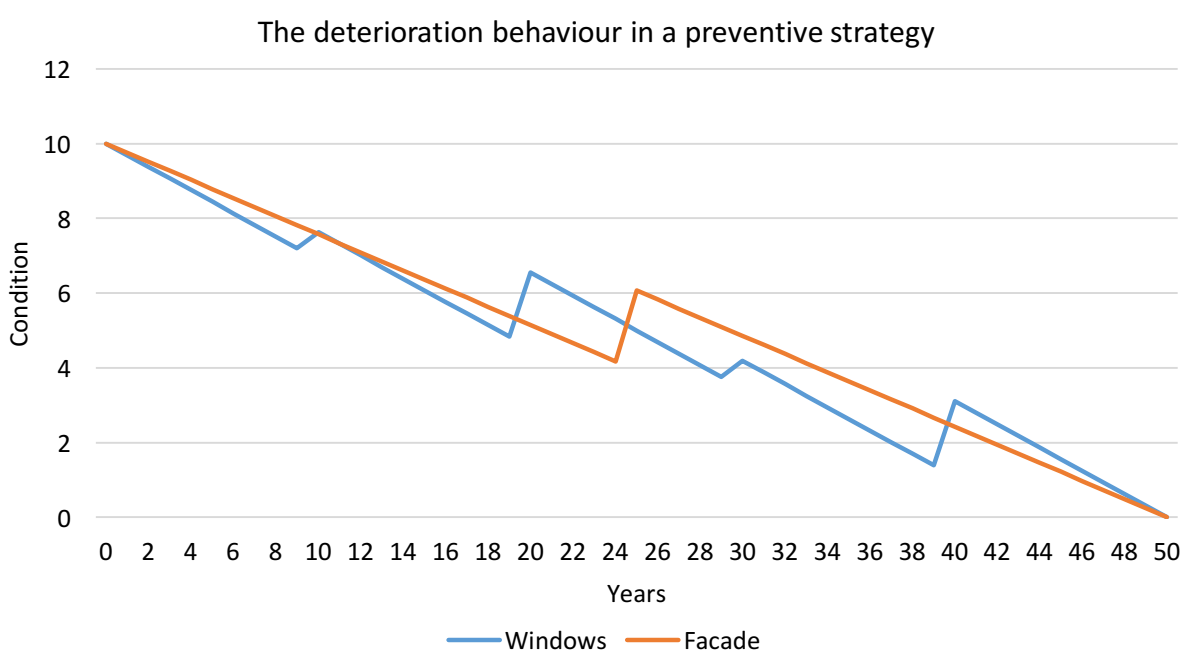


Figure 5-13: The service life and deterioration behavior for two building elements in preventive maintenance strategy

In this case, given that the replacement and preventive maintenance costs are known²¹, this combination can only be economically justified if the savings gained from this combination exceeds 86 Kr/m² (façade area). This shows that if calculations are not made based on life

²¹ SABO's nyckeltal för underhåll av bostäder, 2014.

cycle cost analysis, given that combining the two measures results in certain amount of savings, it would be considered a profitable choice regardless.

On the other hand, if a preventive strategy has been in place, both measures would have reached the minimum condition level at the same time. So, not only the service life for both measures have been increased, the savings made by combining the replacement work won't result in losses through premature replacement of the parts (in this case, façade). In this example, considering all the costs for preventive maintenance measures, the preventive strategy results in 138 Kr/m² (façade area) savings compare to the case with replacement work carried out at year 32.

This example shows many benefits of a preventive strategy, the most important of which is the opportunity it offers to control the replacement period through application of certain preventive measures. It is important to mention that the values given above only applies to this example. These values are sensitive toward changes in discount rate. The value used for discount rate in these calculations is 6% nominal.

From these results, already it can be seen that there are always benefits in maintaining properties. It also was realized that modernization is fundamental, not only to comply with the recognized utility value, but also to prolong the economic life of the respective properties. The differences in housing market conditions also were discussed for central and suburban areas and it was shown that it is financially more difficult for housing companies to maintain and renovate properties in less attractive markets.

One of the issues that have not been discussed yet, is the application of energy efficiency measures in buildings which are subject to extensive maintenance and renovation (modernization) measures.

5.2. Energy efficiency

In the Swedish rental market, energy efficiency is often looked upon as extra costly measures rather than profitable investments. Maybe the reason behind, lies within the Swedish rent negotiation system, where energy efficiency, regardless of its importance in the living quality of the tenants, is not recognized as utility value. This characteristic of the rental market can obviously reduce incentives toward energy efficiency. On the other hand, although there are requirements for the energy performance in new constructions, in renovation, only the affected parts of the property are subject to such requirements.

Regardless of all the external variants affecting the decision for energy efficiency mentioned above, there are also number of internal issues hindering the progress of energy efficiency investment in real estate sector. In the beginning of this section, some of these factors are explained and differences are discussed in order to clarify general facts as well as misconceptions regarding the performance and the economy of energy efficiency

measures. Then, the application of energy efficiency in renovation is examined on the sample properties to better illustrate the benefits of energy efficiency to the economy of the respective housing company.

5.2.1. Marginal costs of energy efficiency

Implementing energy efficiency measures in buildings subject to renovation reduces the total costs of investment since a share of the costs associated with energy efficiency measures are already seen in renovation expenditures. Therefore, subtracting this share of the cost, the profitability for energy efficiency investment should only be evaluated using the marginal costs. The subtracted share of the total costs which can be referred to as the fixed costs, are those costs related to the installation of the measures rather than the costs of materials. Therefore, the marginal costs are lower for those measures that require expensive adjustments/preparation, i.e. Water and sewage, Heat recovery, windows and façade.

Figure below, Figure 5-14, shows the difference between the full/marginal costs of implementing energy efficiency measures for two investment periods of 20 and 40 years, (Westerbjörk, 2015). Values given in the figure below, are the life cycle investment costs for each measure with its respective profitability period.

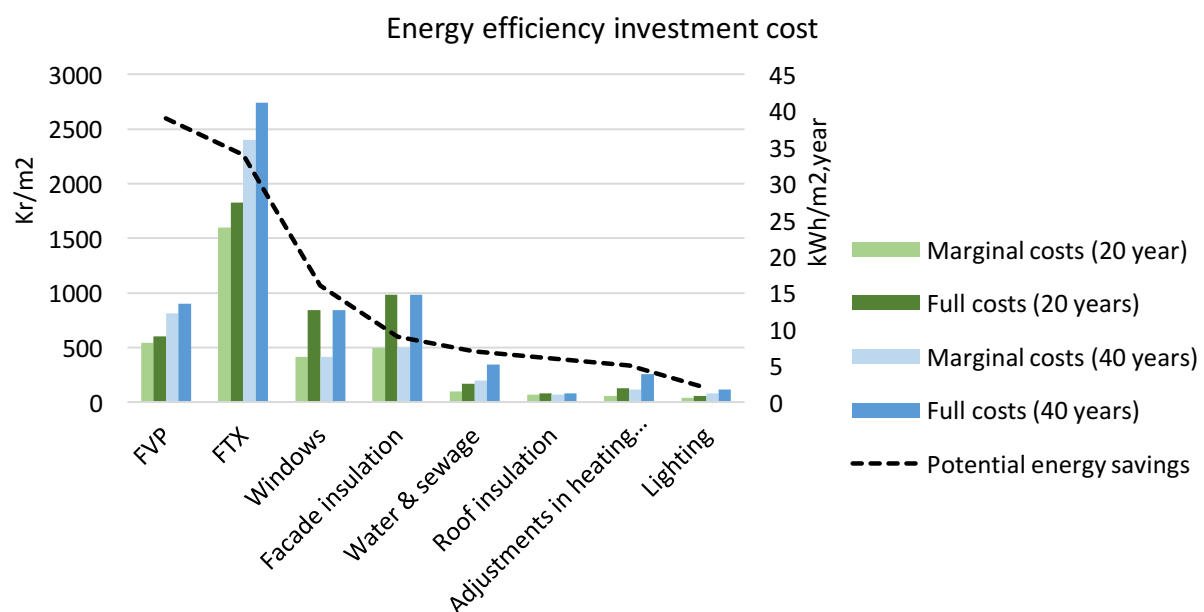


Figure 5-14: Marginal and full investments costs and the average potential energy savings for different energy efficiency measures

One interesting observation from this figure, Figure 5-14, is the noticeable difference between the marginal and full investment costs in costly measures, i.e. façade insulation and upgrading windows which have the longest service life amongst other efficiency measures. For property owners, the chance to implement such measures at half the full

investment costs only shows up every 40 to 50 years which indicates the importance of prioritizing long lasting parts when planning for energy efficiency investments.

From the figure above, the two efficiency measures which offer the highest savings potential are the FVP (exhaust heat pump) and the FTX (Exhaust heat recovery) measures. Both these measures offer heat recovery from the exhaust air thus are not implemented together (usually). Although the FVP system seems to be the obvious choice between the two measures, considering the huge difference in their cost-effectiveness, the choice of each is dependent on the existing ventilation system in the respective property. The FTX system requires both supply and exhaust ducts while the FVP system can be installed in properties with an exhaust duct alone. Besides, installing FTX system often requires bigger space than the FVP system considering the size of FTX units. Installation of FTX in properties with only the exhaust duct requires alteration in the design which imposes extra costs to the housing company. These two could be amongst reasons behind the higher cost of FTX system.

All the given measures in the figure above except the FTX measure will be used for energy efficiency in the sample buildings in the following discussions in the respective section. The total energy savings offered using these measures are calculated at 84 kWh/(m², year) whereas the total marginal costs will become 2194 Kr/m², (to total costs used in the following discussions is assumed to be 3000 Kr/m² which is higher than the marginal costs and is in line with the average value obtained from previous renovation projects). The amount of energy savings corresponds to 48% reduction in total energy use which is below the average of 60% from previous renovation projects.

It is important to mention that the potential savings offered by each efficiency measure used above are the average values the extent of which vary extensively. This variation is partly influenced by the energy performance of the properties before the utilization of the respective measure. Properties with low energy performance offer better potential for energy savings which translates to better profitability in energy efficiency investments. For example, the FTX system has shown to be capable of offering from 17 up to 56 kWh/(m², year) of energy savings, (Högdal, 2013a), depending on the energy performance of the respective properties.

Another very important issue which should be mentioned here is that, constructional thermal insulation (façade, roof, attic, basement and so on) have a very long service life (sometimes even more than 50 year) thus become substantially more expensive to implement in the future (up to factor 3), (Jakob, 2006). Therefore, considering the very low risks involved, these measures should be looked upon as an insurance policy which can ensure the thermal performance of the property for a very long time to come.

In the profitability of energy efficiency investments, investors are rather sceptical. Being uncertain results in high risks associated with such investments. It is, In the end, in the hand of the investor, whose skills, knowledge and motivation play an important role in the final decision made.

5.2.2. Measurements vs. calculations

One of the factors often discussed regarding the high risks associated with investments in energy efficiency, is the uncertainty in the final performance of the energy efficiency measures. It might be believed that the calculated energy savings rarely match the post-renovation measurements. While being true in some renovation projects, it is most often the opposite specially when individual measuring of hot water and electricity is installed in the apartments.

In the figure below, Figure 5-15, the difference between the calculated and measured energy savings is given from 9 renovation projects in Sweden. As it is shown in the figure, on average, the calculated energy savings are lower than the measured values after renovation.

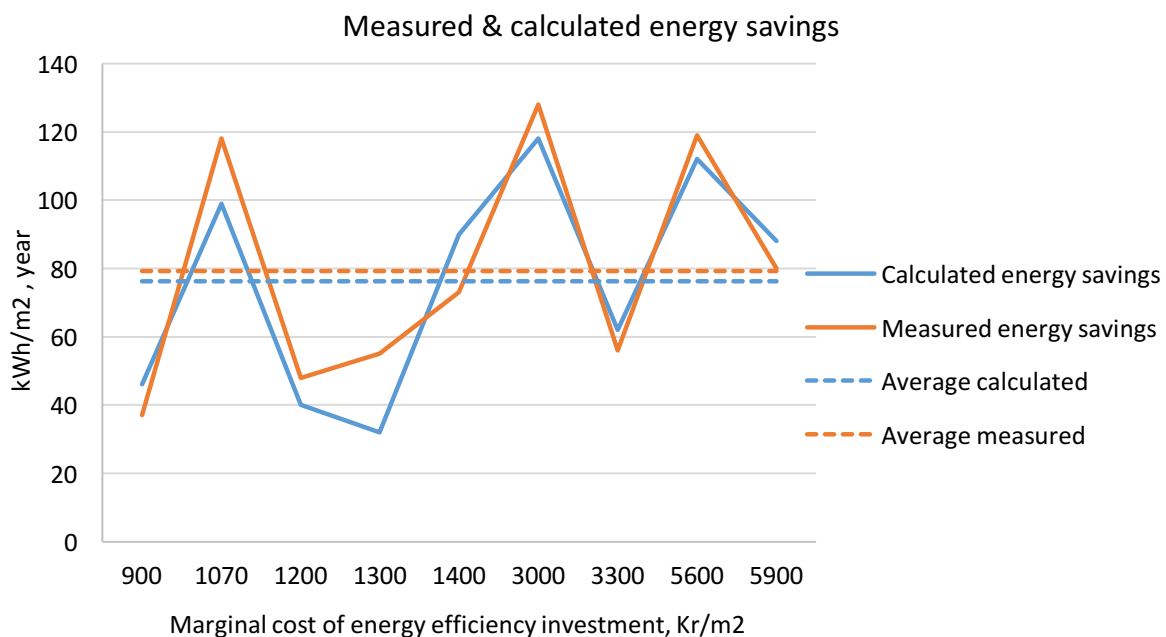


Figure 5-15: Calculated vs. measured energy savings from 9 renovation projects in Sweden, (stockholms stad)

Also given in the figure above, are the marginal costs of energy efficiency investment and the respective energy savings. The interesting unpredictable relationship between the energy savings and the respective investment costs show that achieving high energy savings does not necessarily require high investment capital. It should always be remembered that, high energy savings is achieved not necessarily with higher investment costs. The optimum combination of measures can result in acceptable investment to saving ratios.

5.2.3. Energy renovation

As discussed earlier, the profitability of energy efficiency investments is strongly influenced by the choice of uncertain variables in the calculation of the profitability. Therefore, the intention in this study is to illustrate the benefits gained from implementation of energy efficiency measures, rather than profitability calculation under given conditions.

One important yet disregarded benefit of improved energy performance of residential buildings is the added market value due to the implementation of energy saving measures. Figure below, Figure 5-16, illustrates how the application of energy efficiency measures can affect the market value thus the economic life of the respective properties. Under given conditions, the economic life of the sample properties reaches its furthest extent at 92 years taking advantage of the improved net operating income due to lower operation costs. Besides, as it is shown in the figure, the sample properties reach their highest market value only after energy renovation which denotes the importance of energy performance in the market positioning of the respective housing company.

As recent studies show, nowadays the real estate market recognises the tangible market value added as a result of improved energy performance, (Morrissey & Horne, 2011; Popescu, Bienert, Schützenhofer, & Boazu, 2012). This added value should be distinguished in profitability evaluation of energy efficiency investments.

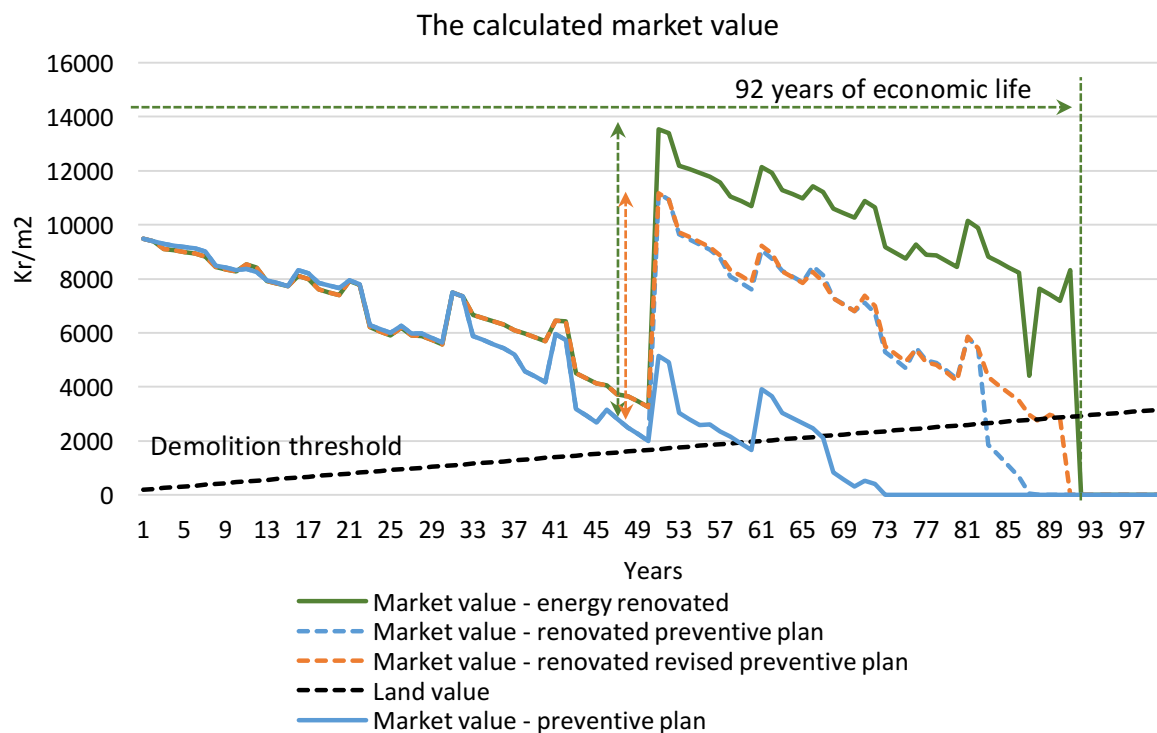


Figure 5-16: The market value of the sample properties with and without implementation of energy efficiency measures as well as the respective land price

Besides all the economic benefits of energy efficiency measures, there are number of important benefits that do not often get adequate attention. For example, one important benefit of energy efficiency measures is the increase in living comfort for occupants. Decreasing the room temperature is often considered as one solution to reduce energy use, (Westerbjörk, 2015). This might not seem an elegant solution when expressed or simply applied as above. Decrease in room temperature, if performed with no consideration decreases tenants comfort and causes indoor quality issues. However, if done based on measurements and further considerations, can be a valuable measure in terms of energy savings. As ((Fanger, 1973)) found, proper insulations of building's envelope and the consequent decrease in temperature difference between the walls and the room temperature enables a decrease in room temperature by 1 degree while keeping the indoor climate in the comfort level.

On the other hand, one key element of windows upgrade measures is noise reductions. Since the majority of multi-family buildings are old and mostly torn, windows and their loose fittings, beside facilitating the heat loss, are the key mean through which outdoor noise is transmitted. This becomes more problematic for apartment buildings close to highways, schools, playgrounds and so on. Upgrading to double/triple glazed windows with rubber seal can reduce the level of noise thus improve the comfort for tenants. (Jakob, 2006) estimates that 10-15 dB decrease in noise specially in noisy locations can lead to the economic benefit of up to 3-7% of the rental income.

The other important benefit of energy efficiency measures is the improvements in the indoor air quality. The use of proper ventilation system can improve the quality of the air thus reduce the health hazardous issues. For properties located in polluted areas, type of ventilation plays an important role in the content of the indoor air. In such locations, air change by means of openings (windows, unfiltered vents, doors and so on) must be limited. Instead a proper ventilation system should be used to treat the incoming outdoor air to the acceptable quality and provide proper air change for the occupants. The lack of proper air change can result in either increased humidity or high pollutant concentration caused by occupants. These pollutants and high humidity can cause serious respiratory health issues for occupants.

These types of benefits mentioned above, should be considered in the profitability evaluation of energy efficiency measures. These benefits along with the salvage value based on the profitability period should be deducted from the investment costs so that only the remaining marginal costs will be attributed to the savings through energy efficiency. Applying these changes can noticeably change the profitability of energy efficiency investments.

5.2.4. Sensitivity analysis

It has been realized that the results for the net present value of the accumulated cash-flows are sensitive towards changes in the discount rate. However, this sensitivity has only been observed to affect the magnitude of the difference between the two maintenance strategies not the actual trend. Therefore, for increasing discount rates, the conclusions stand correct but the difference between the two cash-flows gets smaller. The same conclusion has been made for the calculations of the market value and consequent economic-life of the properties.

5.3. Sustainable urban development

As discussed earlier, renovation (modernization) is essential to the building and its owner. In a normal housing condition, the issues leading to buildings' obsolescence are both external (social) instruments and internal economic incentives which together motivate housing companies to plan for modernization. The housing market influenced by the society sets limits for recognized utility value and building owners need to modernize their properties so that they comply to the recognized utility value if buildings' optimum economic life is desired.

In less-attractive areas with socio-economic issues, the low willingness to pay won't allow for adjustments to the recognized utility value (modernization). Therefore, less comprehensive renovation should be carried out so that the cost-benefits can be optimized. Such renovations won't allow for positive changes in the market.

In order to change the dynamic of the housing market in such location, socio-economic problems should be attended. One of the main topics in Million Homes Programme areas has been the segregation issue. The definition of a problem (segregation) is very important to have in mind when trying to eliminate the problem. Segregation is defined as homogeneity of the proportions of population throughout a defined space. The dissimilarity can occur based on socio-economic, religious or ethnic grounds, (Massey, D.; Denton, 1990).

When discussing the segregation issue, attentions are mainly paid to the effects of renovation and the consequent rent increase on existing tenants and relocation problems, (Boverket, 2014, 2015a). Segregation discussed as such, outlines the renovation area as the defined space for the problem. The issue with this assumption is that, it only attends the segregation problem within the respective area, not the society as a whole. It is important to have in mind that the majority of the multi-family buildings from the million programme are located in such problematic areas. If efforts have been made and the rent increase has been adopted so that tenants are not forced to move out, such segregated areas have just become renovated segregated areas. It is important to understand that this discussion does not by any mean oppose the necessity of adoptive rent increase. The aim is to convey the

message that, while the rent increase should be controlled so that low-income tenants are not forced to move, the segregation issue should be discussed from a broader perspective. The problem is that, the perceived image of such locations to outsiders obstructs incentives to move in or to invest in such areas.

This disrupted picture has been formed not only based on differences in ethnical or religious grounds but also the safety and the security of such locations. Besides, the high risks associated with investment in such locations is strongly influenced by current and perceived future market trends. Therefore, the solution to segregation problem, if tenants are not to move out, is to provide a condition so that outsiders are willing to move in and bring investments. To achieve this condition, not only current properties need to be renovated but new residential and service spaces must be added so that the population in such areas become more homogeneous.

To achieve such condition, a sustainable renovation plan is required. Sustainability in such planning should be dealt with from all three perspectives; ecological; financial and social. Financial sustainability should deal with both the investors' (housing companies) and the consumers' economy (tenants). Both of these have been discussed in this study. However, there are two more groups the economy of which is important to include in all discussions.

First, the prospective tenants whose incentives to move in are greatly influenced by the overall picture of the area and the new rents set. Since the new rents are considered to have the economy of the current occupants in to account (the low-income families), it automatically includes prospective tenants. However, the selection process should be adjusted so that the whole area can benefit from the new mixture in the long run. Of course, achieving such optimized process is difficult and needs infrastructural support.

Second, are the outside businesses and investors whose investments in the area is of crucial importance. For this group, safety and security of the area is one important factor. The safety and security of the area can be easily improved to reduce the crime rate. However, another important factor for this group is the future market prognosis of the area. Fixing this issue in deprived areas however not easy to achieve, will automatically recover the disrupted picture of the area as well.

As for the social sustainability, a better mixed population of different financial, ethnical and religious backgrounds is required. As also discussed in (Boverket, 2015a), it is believed that such locations during time have formed special culture which its existence is essential to inhabitants in each respective location. Comprehensive renovation by no mean should result in destruction of such cultures, as their absence can result in further social deficiencies. Therefore, not only these special characteristics of such locations should be preserved, they need to be promoted and advertised so that in the end while mixed with other cultures, a cohesive well-functioning society is formed.

Finally, as for the ecological aspect, a number of solutions can be introduced so that the environment is also well preserved. Implementation of energy efficiency measures is one important way to tackle the environmental issues. Moreover, introduction of renewable energy technologies can further enhance the environmental performance of the area, i.e. solar panels, wind turbines, geothermal energy and so on. These technologies not only help improving the environmental performance but also promote the area in the eyes of investors.

When evaluating the profitability of renovation alternatives, most often social sustainability is not taken into account. The reason is that it is difficult to present social benefits gained from comprehensive renovation projects in monetary terms. However, this difficulty should not result in negligence of such benefits. In the absence of social sustainability, the market continues to evolve as usual in case of which, as discussed before, the low willingness to pay for higher rents can alter the pace of renovation activities. Since for the investor (the housing company) there is no benefit gained from modernization in such locations, properties are left at current state. The problem is that in such situation with no prospective changes in the market, maintenance which produces no extra income is also in the risk of negligence. Following this path in long term could result in creation of slums. This scenario furthermore increases the regional imbalance making it more difficult for low-income families to find attractive and cheap apartments.

In a case where the housing company decides to include social sustainability and plan for a prospering market in the future in the expense of low/no benefit in the time of renovation, the level of accepted service quality can increase in time. An example of such situation is the Gårdsten project in the northern part of Gothenburg. The Gårdsten project was not a profitable investment in pure constructional terms, (Lind, 2007). Nonetheless, the decision had been made to transform the once deprived market into a well-functioning market through an extensive social development project. Today not only Gårdsten is no longer perceived as a deprived area with a poor housing market, it is indeed very successful in attracting new tenants and business ventures to the area. This at time unprofitable plan, which has turned Gårdsten area upside down, is estimated to have had socio-economic gain on the level of 300 million Kr, the effects of which more than outweigh its negative financial results (Lind, 2007).

6. Conclusions

Considering the high share of residential buildings in the total energy use in Sweden, having the ambitious national energy and climate goals in mind, the real estate sector and its issues have been under a lot of attention since early days. The Swedish real estate sector has often been identified with its ambitious public housing programme during the record years (1960-1974). This was at the time the largest housing programme per capita in the world where more than a million apartments were built in a nation with a population of 8 million. These apartments once being the pride of a nation, are facing a lot of problems today, ranging from vacancy and unacceptable physical condition to very poor energy performance.

These buildings at the verge of their service/economic life are in need of extensive maintenance and renovation measures. Considering the technological development today, the problem with maintenance and renovation remains to be the financial constraints. These financial difficulties are the result of both internal (property management) and external (market variants) system deficiencies. The initial aim of this research project therefore has been to study the current situation and identify these problems.

In doing so, the Swedish rental housing market has been studied and its contribution in the creation of the current situation has been discussed extensively. The rent negotiation system and its principles has been identified as one of the reasons why maintenance and energy efficiency have become such financial burdens while renovation (modernization) has transformed into an instrument to push the economic constraints.

Besides, some of the regulatory issues have been recognized to have roles in the formation of such financial difficulties. For example, the limitation on maintenance provisions could have a considerable effect on the financial performance of the municipal housing companies. Or despite the positive effects of the component depreciation approach, the limitation in the use of different depreciation methods could limit the income-optimization flexibility specially in smaller housing companies.

Still and all, on top of such external limitations, there are internal system deficiencies within the managing housing companies which further limit the progress of renovation and energy efficiency. Such deficiencies have been observed in both the profitability assessment of renovation and energy efficiency investments and the choice of maintenance strategies.

Housing companies show different level of commitment toward social sustainability and energy efficiency. The profitability calculations are quite sensitive towards those variables the assumption of which is in the hand of the decision makers. Therefore, the profitability

of investments in both renovation and energy efficiencies is strongly influenced by individuals' motivations and incentives.

On the other hand, considering the current situation of the multi-family buildings, it has been noticed that maintenance measures in many cases have been neglected or postponed either as a maintenance strategy or to optimize income. In any event, it seemed appropriate to evaluate the economic effects of such strategies. Therefore, the deterioration behaviour of different building parts has been studied to find correlation between the maintenance costs, maintenance quality and its effects on the service life of the respective parts. As a result, a simple method has been developed which has enabled us to evaluate the economy of different maintenance strategies.

Afterward, the method has been applied to two common maintenance strategies in residential properties (the preventive and corrective maintenance strategies) to evaluate the effects of each strategy on the economy of the housing companies as well as the economic life of the respective properties. The results from this evaluation demonstrated the positive effects of preventive maintenance strategy on all the studied aspects, i.e. the market value, the economic life, the financial performance and the economy of the forthcoming renovation plan. Furthermore, it has been shown that the consideration of planned renovation in the making of the maintenance strategy can influence both the profitability of the investment and the economic life of the renovated property.

In the end, the general facts and misconceptions regarding investments in energy efficiency have been explained and the positive effects of such measures on the economy of the investor as well as the economic life of the respective properties have been illustrated. It is important to study how the combination, timing and the order of energy efficiency measures can affect its investment profitability.

Considering the current need for renovation and the difficulty in the financing of such projects, from the results of this study, it has been noticed that the use of more sophisticated deterioration model can help housing companies (to systematically include renovation and energy efficiency in the maintenance strategy) and create a prioritized action plan through partial maintenance and renovation of the poorly conditioned housing stock. The partial renovation can form in the shape of modernization alternatives or only for aesthetic reasons to promote the market condition of the respective properties. In either case, the choice of building parts and the time of maintenance/renovation can be estimated using the deterioration model. Likewise, the promising features of this method can be used in optimization of the preventive maintenance plan with regard to external requirements, such as the energy efficiency.

7. References

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8. Appendix

The table below shows the building elements from SABO's registry (SABO, 2013b) including the time for each preventive measure (Year), the replacement time (Year), the costs of preventive measures (Kr) and the reinstatement costs (Kr) which have been adopted to the sample buildings' specifications in this study.

		Year	5	10	15	20	25	30	35	40	45	50
Roof	Clay tiles	Repair					477782					
	Gutters	Replacement										1627363
	Downpipes	Replacement								78163		
	Safety eq.	Replacement								45274		
	Ventilation eq.	Repainting			16000			16000		406511		
Façade	Bricks	Adjustments								80000		
		Cleaning					862260					
		Replacement										1213462
Windows	Wooden, 3m ²	Adjustments				681384				681384		
		Repainting outside		334224				334224				
		Repainting inside				241296				241296		
		Replacement										3400056
Doors	Wooden, Main entry	Repair		23388		23388			23388		23388	
	Wooden, Inner doors	Replacement					97484					97484
	Wooden	Repainting			200592						200592	
		Replacement						543168				
Floors	Wooden	Sanding, varnishing			554016			554016				
		Replacement								2358048		
	Plastic mat	Replacement					227712					227712
	Concrete	Cleaning			37632			37632			37632	
Walls	Apartments	Repainting			635040			635040			635040	
	Bathrooms	Repainting			276696			276696			276696	
	Laundry rooms	Repainting		30744		30744		30744		30744		30744
	Corridor	Repainting			422004			422004			422004	

Ceilings	Concrete, Inner ceiling	Repainting					801792			801792	
	Bathroom ceiling	Repainting					70272			70272	
Bathroom	Toilet fittings	Repair			46464						46464
		Replacement									
	Shower fittings	Repair			110256						110256
		Replacement									
Kitchen fixtures	Kitchen	Repainting					90000				
	fixtures and equipment	Repair					202704				
		Replacement							3366528		
Stairwells	Simple stairwell	Painting		25140				25140			25140
		Repair					40192				
Laundry		Replacement							74196		
		Repair					211292			211292	
Sewage piping	Horizontal	Replacement									612058
	Vertical	Replacement									457713
Water piping and equipment	Horizontal pipe runs	Replacement									1087834
	Vertical pipe runs	Replacement									616493
	Expansion tank	Service					4400		4400		
		Replacement							29292		
	Circulation pump	Service		2040							2040
		Replacement							13620		
Heating system	DH centre	Service					59393			59393	
		Replacement									
	Heat exchanger	Service		9150					9150		9150
		Replacement									

Heating distribution	Radiators with vent	Service		229652		229652				
		Replacement								15228375
	Horizontal piping	Repair		114826		114826				
	Vertical piping	Replacement								748349
		Repair			63352		63352			
	Circulation pump	Replacement								
Air distribution		Service		8700				8700		8700
		Replacement				58000			58000	
	Exhaust fan system	Service			1992					1992
		Replacement						9960		
	Exhaust inlets	Service		8640				8640		
		Replacement								43104
Electricity	Kitchen vent	Service		28080		28080			28080	28080
		Replacement						140400		
	Power, apartments	Replacement						456972		
	Power, building	Replacement						2173776		
	Power, Laundry	Replacement						59820		
	Armature, apartments	Replacement					376154			376154
Lighting	Armature, laundry	Replacement					9958			9958
	Changer	Replacement				136000			136000	
Garbage Control centre	For piping and air distribution	Service	7919	7919		7919	7919		7919	7919
		Replacement			55433			55433		55433

